CHARLES UNIVERSITY

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Effect of rest duration in explosive strength training of lower extremities

Dissertation

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Declaration

I declare that I have created this dissertation on my own and that I have cited all used information sources and literature. This work, or its substantial part, has not been previously used to obtain any academic degree.

Prague, June 2024

Mgr. Martin Tino Janikov

Acknowledgements

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Abstract

Title: Effect of rest duration in explosive strength training of lower extremities

Objectives: This dissertation aims to: i) review the effects of rest durations in explosive strength training of the lower extremities; ii) test how different inter-repetition rest durations impact acute onset of fatigue-related performance changes during repeated jumps; iii) assess the effect of impact forces on cumulative fatigue in intermittent vertical jumps; iv) compare the take-off and landing parameters of three common plyometric exercises.

Methods: A systematic literature review and two quasi-randomized cross-over data collections were conducted. The review screened four databases for studies on rest durations in jump training, including healthy participants of any age, gender, or training level. The first data collection involved 20 recreationally trained men performing three types of jumps: countermovement jumps (CMJ), hurdle jumps (HJ), and box jumps (BJ). Ground reaction forces, movement velocities, and displacements were measured. The second data collection measured heart rate, blood lactate concentration, and localized muscle contractile properties before and after 50 CMJs with varying inter-repetition rest durations (0 to 12 seconds) in 14 recreationally trained men. Velocities, displacements, and rating of perceived exertion (RPE) were also recorded. Post hoc correlation and subgroup analyses were performed to explore the relationship between jumping performance and participant characteristics.

Results: The review showed that manipulating inter-repetition and inter-set rest intervals, as well as using rest redistribution can reduce performance loss in demanding plyometric sessions with specific rest requirements depending on other training parameters (e.g., training volume), age, and training status. However, forming a recommendation of specific rest durations was not possible. Our empirical data suggested that CMJ, HJ, and BJ share similar key take-off characteristics (i.e., concentric velocity, peak vertical and resultant force, rate of force development, and total impulsion time), with differences including smaller horizontal force and deeper countermovement in CMJ and lower impact forces in BJ. Outcomes from 30 repeated jumps did not show benefits of reduced impact forces in preventing performance loss due to cumulative fatigue, although thus effect may have been masked by experimental limitations. Inter-repetition rest durations of 0 to 4 seconds reduced fatigue-related changes, including jump height, take-off velocities, heart rate, blood lactate concentration, muscle contractile properties, and RPE. Correlation and subgroup analyses found some significant relationships and differences tied mainly to maximal strength and jumping abilities of our samples, but these findings are tentative due to small sample sizes.

Conclusion: As little as 4 seconds of inter-repetition rest can effectively mitigate performance losses in explosive strength training of lower extremities, making long inter-set rest intervals unnecessary. Optimal inter-repetition rest intervals could enhance training by maintaining performance over larger training volumes, reducing recovery time, and increasing efficiency by preventing over-resting. Our findings may apply to other common plyometric exercises like HJ and BJ due to many kinetic similarities to CMJ. The effect of impact forces on fatigue-related onset of performance losses in repeated jumps remains unclear. More research should follow to gain more detailed insights into the effects of very short inter-repetition rest intervals between 0 and 4 seconds, long-term training effects, and validate our results with larger and more diverse samples.

Keywords: countermovement jump, plyometrics, fatigue, exertion, recovery, load management, exercise selection, impact force

Abstrakt

Název: Efekt délky odpočinku v tréninku explozivní síly dolních končetin

Cíle: Tato disertační práce si klade za cíl: i) přezkoumat účinky různých typů odpočinků v kontextu explozivního silového tréninku dolních končetin; ii) otestovat, jak různé délky odpočinku mezi jednotlivými výskoky ovlivní akutní nástup změn ve výkonu souvisejících s kumulativní únavou v průběhu série výskoků; iii) posoudit vliv nárazových sil na kumulativní únavu při sérii výskoků; iv) porovnat parametry odrazu a dopadu u tří často využívaných plyometrických cvičení.

Metody: Byla provedena systematická literární rešerše a dvě kvazi-randomizované zkřížené vnitrosubjektové sběry dat. Rešerše hledala studie zabývající se intervaly odpočinku v tréninků výskoků se zdravými účastníky jakéhokoliv věku, pohlaví a trénovanosti napříč čtyřmi databázemi. První sběr dat zahrnoval 20 rekreačně trénovaných mužů, kteří prováděli tři typy výskoků: výskoky s protipohybem, přeskoky překážky a výskoky na bednu. V průběhu intervence byly měřeny reakční síly podložky, rychlosti a vzdálenosti pohybů. Druhý sběr dat měřil srdeční frekvenci, koncentraci laktátu v krvi a lokální kontraktilní vlastnosti svalů u 14 rekreačně trénovaných mužů před a po 50 výskocích s protipohybem s různými délkami odpočinku mezi jednotlivými výskoky (0 až 12 sekund). V průběhu intervence byly zaznamenány rychlosti a vzdálenosti pohybů a po posledním skoku také subjektivní hodnocení míry zátěže. Na závěr byly provedeny post hoc korelační a podskupinové analýzy pro posouzení vztahu mezi deskriptivními charakteristikami účastníků a výkonech ve výše popsaných skokanských intervencích.

Výsledky: Rešerše ukázala, že manipulace délky odpočinku mezi jednotlivými skoky a mezi sériemi skoků, stejně jako redistribuce odpočinku, mohou minimalizovat pokles výkonu v náročných plyometrických tréninkových jednotkách. Specifické požadavky na délku odpočinku závisí na tréninkových parametrech (např. tréninkovém objemu), věku a trénovanosti cvičenců. Nicméně, prozatím nebylo možné formulovat konkrétní doporučení ohledně délek odpočinků. Naše empirická data naznačují, že výskoky s protipohybem, přeskoky překážek a výskoky na bednu mají podobné klíčové parametry odrazu (např. koncentrickou rychlost, maximální vertikální a výslednou sílu, rychlost rozvoje síly a celkovou dobu impulsu), ale i několik odlišností, jako například nižší horizontální sílu a hlubší protipohyb u výskoků s protipohybem a nižší nárazové síly u výskoků na bednu. Výsledky 30 opakovaných výskoků neprokázaly pozitivní efekt snížení nárazových sil za účelem minimalizace poklesu výkonu vlivem kumulativní únavy, ačkoli tento efekt mohl být maskován limitacemi experimentu. Odpočinek v délce 0 až 4 sekund mezi jednotlivými výskoky významně minimalizoval změny související s únavou – výšku výskoku, odrazovou rychlost, srdeční frekvenci, koncentraci laktátu v krvi, svalovou kontraktibilitu a subjektivní míru zátěže. Korelační a podskupinová analýza odhalila několik významných vztahů a rozdílů, zejména týkající se úrovně maximální síly a výkonů v testech maximálního výskoku, avšak při interpretaci výsledky těchto analýz by měla být brána v potaz malá velikost výzkumného vzorku.

Závěr: Již pouhé 4 sekundy odpočinku mezi jednotlivými výskoky v sérii mohou efektivně zmírnit ztráty výkonu v explozivním silovém tréninku dolních končetin, což znamená, že dlouhé intervaly odpočinku mezi sériemi nejsou nutné. Optimální doba odpočinku mezi jednotlivými výskoky může podpořit trénink tím, že zachová vysoký výkon napříč větším tréninkovým objemem, zkrátí dobu potřebnou pro zotavení a zvýší efektivitu tréninku tím, že předejde neadekvátně dlouhému odpočinku. Naše výsledky jsou pravděpodobně aplikovatelné i na další běžná plyometrická cvičení jako přeskoky překážek a výskoky na bednu, vzhledem k mnoha kinetickým podobnostem s výskokem s protipohybem. Vliv nárazových sil na ztrátu výkonu související s kumulativní únavou při opakovaných výskocích zůstává nejasný. Další výzkum by se měl zaměřit na akutní a chronické účinky velice krátkých intervalů odpočinku mezi jednotlivými výskoky v rozsahu 0 a 4 sekundy a na ověření našich výsledků na různorodých a větších vzorcích.

Klíčová slova: výskok s protipohybem, plyometrie, únava, námaha, zotavení, regulace zátěže, výběr cvičení, nárazová síla.

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List of abbreviations

1RM	One repetition maximum
ANOVA	Analysis of variance
BJ	Box jump
CI	Confidence interval
CMJ	Countermovement jump
DJ	Drop jump
HJ	Hurdle jump
IF-r	Peak resultant landing force
IF-v	Peak vertical landing force
PF-h	Peak horizontal take-off force
PF-r	Peak resultant take-off force
PF-v	Peak vertical take-off force
RFD	Average take-off rate of force development
RPE	Rating of perceived exertion
RSI	Reactive strength index
SD	Standard deviation
SJ	Squat jump

1 Introduction

A superior level of muscular strength, described as the ability to produce force against an external resistance (Siff, 2000; Stone, 1993), is strongly correlated to multiple factors enhancing athletic performance (Suchomel et al., 2016). However, in a competitive sport setting, the speed with which strength is expressed can be equally as important as its magnitude. Performance in sports incorporating various types of jumping, sprinting, and rapid changes of direction is greatly affected by athlete's lower body power output (Cerrah et al., 2014; Gabbett & Georgieff, 2007; Hoffman et al., 1996; le Gall et al., 2010), which colloquially refers to the ability to produce a large amount of force in a short amount of time (Enoka, 2008).

Taking this into account, it should not come as a surprise that improving power output has been reported to be one of the main aims of strength and conditioning coaches across various sports and age groups (Duehring et al., 2009; Durell et al., 2003; Ebben et al., 2004, 2005; Ebben & Blackard, 2001; Simenz et al., 2005; Weldon et al., 2020). Although there are a variety of training methods that can result in improved power output, probably the easiest to implement and progress in most training environments is plyometric training. Plyometric training requires little to no equipment and has been repeatedly validated as effective for improving ability to produce power (Bedoya et al., 2015; Johnson et al., 2011; Markovic, 2007; Slimani et al., 2016; Stojanović et al., 2017).

Although the available literature provides a high level of certainty in effectiveness of plyometric training, the confidence in ways to optimize the plethora of training parameters as well as identification and in-depth understanding of many factors which could influence them is still lagging. Therefore, in this dissertation, we set out to summarize the state of knowledge regarding factors which influence programming decisions regarding rest intervals and to test the effect of some of these factors. Specifically, effects of inter-repetition rest duration to prevent acute fatigue-related performance loss in a set of repeated jumps in the novel way which would add value to both research and training practice.

THEORETICAL PART

2 Definitions and foundational concepts

As outlined in the introduction, a key objective of strength training across various athletic disciplines is to enhance explosive strength capabilities. Explosive strength can be defined as the maximal or near-maximal rate of concentric force production throughout the range of motion specific for a given movement task (Stone, 1993). While genetic predispositions play a major role in dictating individual's explosive strength potential (Beunen & Thomis, 2006; Calvo et al., 2002; Hughes et al., 2011), it can be improved through well designed training program (L. Chen et al., 2023; Pajerska et al., 2021; Santos & Janeira, 2008). In sport settings, explosive strength is often quantified using power output, a scalar quantity measured as the product of average force and average velocity (McGinnis, 2013). To enhance power output through training, specific adaptations in key underlying biomechanical factors must be achieved, such as an increased number and firing rate of motor units or an increased muscle cross-sectional area (McBride, 2016).

The principle of specificity is one of the core concepts of strength training, often referred to as the SAID principle, which stands for "specific adaptations to imposed demands." This principle indicates that training adaptations are dictated by the nature of the training stimulus (Sheppard & Triplett, 2016). However, training specificity should not be viewed binarily – specific or non-specific. Instead, it can be better understood as a spectrum ranging from less to more specific. For example, to improve vertical jump performance, one could select a less specific exercise such as the seated leg press or a more specific exercise like the barbell squat. The similarities in movement patterns between the squat and vertical jump make the squat more specific than the leg press, though neither exercise perfectly replicates all aspects of a vertical jump.

There are at least ten factors to consider when assessing the specificity of a training stimulus: movement pattern, contraction type, muscle length, movement velocity, force of contraction, muscle fiber recruitment, metabolism, biochemical adaptation, flexibility, and fatigue (Verkhoshansky & Siff, 2009). Based on these factors, performing a barbell squat for vertical jump development might provide similar stimulation regarding movement pattern, contraction type, and muscle lengths, but it will not match the movement velocities achieved during the vertical jump. This mismatch in movement velocity has been shown to reduce the training effect (Behm & Sale, 1993). Therefore, other training variables such as movement velocity, training volume and intensity, proximity to failure, and rest intervals can be equally important in determining specific training outcomes as exercise selection.

Strength training methods are represented by concrete levels of the aforementioned training variables, which determine how individual exercise ought to be performed and what training effects can be expected (Verkhoshansky & Verkhoshansky, 2011). Multiple training methods, such as plyometrics, weightlifting derivatives, potentiation complexes, eccentric training, training with variable resistance, and ballistic training, can be used to enhance power output capabilities (Suchomel et al., 2018). There are important differences in the required equipment, skill prerequisites, and athlete's training status for each of these methods to be effectively implemented in a training process. For example, weightlifting derivatives require access to special equipment (e.g., barbells, dumbbells, or kettlebells), a higher level of balance and joint stability, as well as mastering relatively complex exercise techniques before they can be effectively used to increase maximal power output in an athlete. Conversely, much less equipment and a lower baseline level of abilities are required to implement and scale plyometric training.

Plyometric training is characterized by quick, powerful concentric movements immediately preceded by an eccentric pre-stretch or countermovement, commonly seen in activities such as jumping, throwing, and running (Potach & Chu, 2016). This movement sequence, known as the stretch-shortening cycle, provides numerous performance benefits, including improvements in vertical jump, running speed, agility, and running economy (Booth & Orr, 2016; Markovic, 2007). Research into the stretch-shortening cycle has identified several underlying mechanisms, such as a tendon's ability to store and release elastic energy, the stiffness and compliance of involved structures, involuntary reflexive processes that regulate joint stiffness and muscle pre-activation, the proximity to optimal muscle length before the concentric phase, and the ratio between fast and slow twitch muscle fiber types in the involved muscels. (Turner & Jeffreys, 2010).

A vertical jump serves as an effective example to demonstrate the influence of stretch-shortening cycle on augmenting power output. It is well-known that a vertical jump from a static squat position without countermovement – squat jump (SJ), which limits the impact of the stretch-shortening cycle, tends to be lower than countermovement jump (CMJ) that utilizes the stretch-shortening cycle through a rapid descend from a standing position immediately before take-off. Further enhancement of jump height can be achieved by increasing the intensity of the stretch-shortening cycle, for example by increasing pre-tension via a faster eccentric velocity during the countermovement, as seen in a drop jump (DJ) from an elevated platform (McBride et al., 2008; McCaulley et al., 2007). The potentiating effect of the stretch-shortening cycle increases with the speed and amplitude of the countermovement (Taube et al., 2012), as long as the forces from the pre-stretch remain within individual's capacity to absorb them (Lees & Fahmi, 1994; Peng, 2011; Voigt et al., 1995).

Since strength training adaptations are velocity-specific (Behm & Sale, 1993; Kanehisa & Miyashita, 1983; Pareja-Blanco, Rodríguez-Rosell, et al., 2017; Pareja-Blanco, Sánchez-Medina, et al., 2017) and most sports are performed without additional load beyond the athlete's body weight, plyometric training has great potential to serve as an effective, activity-specific, high-velocity, bodyweight training tool in many strength and conditioning programs. However, each training stimulus that results in fitness improvements simultaneously induces some amount of fatigue. This fatigue can temporarily mask some or all of the positive effect of training, a concept known as the fitness-fatigue model (Chiu & Barnes, 2003).

Multiple definitions of fatigue are used in research and training practice, which can complicate comparisons and communication of outcomes. For example, some common definitions include: "a loss of maximum force-generating capacity", "failure to maintain the required or expected force", "failure to generate output from the motor cortex", "failure to continue working at a given exercise intensity", and "progressive reduction in voluntary activation of muscle during exercise" (Phillips, 2015). These varied definitions can lead to practical problems, as depending on the task at hand, there might be a large gap between the points at which capacity to generate maximum force is lost, expected force cannot be maintained, and the motor cortex fails to generate output.

Fatigue in sport and exercise is studied using various methods, including data collected directly during sport competitions and during sport simulations. These methods are ecologically valid but technologically and logistically limited. In contrast, laboratory-based methods such as repeated muscle contractions and artificial muscle stimulation provide large amounts of data, although they are bound to laboratory environments, which are far from sport-specific conditions (Cairns, 2013).

Currently, there is no single definitive marker of fatigue, so researchers must use various markers depending on the nature of the activity and available methods. Useful markers for detecting elevated fatigue include biochemical markers (e.g., lactate, creatine kinase, or adenosine), endocrine markers (e.g., thyroid or cortisol-testosterone ratio), immunological markers (e.g., blood leukocyte concentration), autonomic nervous system alterations (e.g., heart rate or heart rate variability), neuromuscular markers (e.g., CMJ performance), psychological questionnaires, and self-reported methods (e.g., rating of perceived exertion scales) (Bestwick-Stevenson et al., 2022; Thorpe et al., 2017). However, fatigue markers should not be confused with the causative mechanisms of fatigue. Factors such as elevated inorganic phosphate in muscle, severe intracellular and extracellular acidosis, cerebral hypoxemia, reduced muscle glycogen, and a lowered trans-sarcolemmal gradient of potassium cation are suggested to be among the main mechanisms causing fatigue during physical activity (Cairns, 2013).

For the purpose of this dissertation, fatigue will be defined as significant detrimental changes in key dependent variables, such as jump height, peak concentric power, peak concentric velocity, rate of force development, and self-reported rating of perceived exertion pointing

Concrete mechanisms and symptoms of fatigue are specific to the activity, athlete, and environment (Knicker et al., 2011). Intense plyometric exercise can induce fatigue, leading to neuromuscular changes that manifest as acute decreases in movement velocity, potentially diminishing the training effect (Nicol et al., 2006). These neuromuscular changes result from a combination of metabolic and mechanical effects, creating a vicious circle of reduced stretch tolerance within the muscle-tendon unit. This reduction leads to elevated peak ground reaction forces and prolonged contact times, subsequently decreasing elastic recoil and increasing work during the take-off phase (Nicol & Komi, 2003).

In common bilateral plyometric exercises, peak vertical ground reaction forces can be as high as 3- to 4-times athlete’s bodyweight (Jensen & Ebben, 2007; Wallace et al., 2010). While such forces might be manageable in isolation, they can become taxing within the context of higher training volumes required for effective power development. Training volume and program duration are crucial parameters to consider for optimizing plyometric training stimulus (Saez de Villarreal Saez et al., 2009, 2012). A meta-analysis investigating the effects of plyometric training on vertical jump performance reported that the best results were achieved by training programs that included at least 50 repetitions of high-effort jump variations (e.g., SJ, CMJ, and DJ) per training session and lasted at least 10 weeks (Saez de Villarreal Saez et al., 2009).

Designing a plyometric program consistent with these recommendations requires careful manipulation of training variables to achieve positive adaptations while preventing excessive fatigue-induced velocity loss (García-Ramos et al., 2015; Hardee et al., 2012; Mora-Custodio et al., 2018). This is particularly important when performing intense training tasks across higher training volumes.

Since rest interval manipulation has already been shown to be effective in managing fatigue in resistance training (Grgic et al., 2018; Tufano et al., 2017), it is reasonable to expect that similar benefits could be expected for plyometric training. However, the effect of rest period manipulation in plyometric training has not yet been investigated as extensively as in resistance training, indicating a need for further research to enable confident recommendations for training practice. Therefore, the aim of this dissertation is to review and expand the current state of knowledge regarding the practical use of rest periods in plyometric training for explosive strength development, with a special focus on inter-repetition rest.

When creating a training program, multiple variations of rest period types are used throughout the process (Table 1). We can categorize these rest periods into two main types: occurring within a single training session and those separating two consecutive training sessions.

Within a single training session, rest periods serve various purposes: they separate consecutive sets of an exercise, as well as individual repetitions or groups of repetitions within a single set. Rest periods occurring between repetitions are often referred to as inter-repetition rest, while inter-set rest describes the rest periods between sets (Tufano et al., 2017). Additionally, in cluster set structure, the rest periods separating groups of repetitions within one set are called intra-set rest (Tufano et al., 2017).

Rest periods between two consecutive training sessions are referred to as inter-day rest (Ramírez-Campillo et al., 2015), usually expressed in the number of hours separating the sessions. Although training frequency is not a true rest period, it is an important training variable closely related to inter-day rest, typically expressed as the number of training sessions within a single week (Schoenfeld et al., 2016).

Table 1. Definitions of rest period types.

Program variable	Definition
Inter-repetition rest	Rest interval between individual repetitions within a single set (Tufano et al., 2017).
Intra-set rest	Rest interval between groups of repetitions within a single set in the context of cluster set structure (Tufano et al., 2017).
Inter-set rest	Rest interval between sets (i.e., multiple repetitions of an exercise performed in sequence) (Tufano et al., 2017).
Inter-day rest	Rest interval between individual plyometric training sessions (Ramírez-Campillo et al., 2015).
Training frequency	The number of training sessions performed in a given period of time, usually a week (Schoenfeld et al., 2016).

3 Factors affecting rest-duration requirements: A systematic literature review

A systematic literature review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). To search electronic databases, the Population, Intervention, Comparison, Outcome (PICO) strategy was used and included terms for plyometric type exercise, types of rest period, set structures, fatigue, and muscle damage. A systematic literature search in four electronic databases: Web of Science, Scopus, SPORTDiscus, and PubMed was conducted first on April 24th, 2020, and additional search was performed on July 19th, 2021. The following three combinations of keywords were searched individually in each database:

a) ((ballistic OR explosive OR jump OR plyometric) AND (inter-set OR interset OR inter-repetition OR interrepetition OR inter-day OR interday OR intra-set OR intraset OR intermittent) AND (duration OR interval OR rest))

b) ((ballistic OR explosive OR jump OR plyometric) AND (exercise OR intervention OR training) AND (cluster OR "set structure" OR "training frequency"))

c) ((ballistic OR explosive OR jump OR plyometric) AND (exercise OR intervention OR training) AND (exhaustion OR fatigue OR "muscle damage" OR soreness))

No publication year restrictions were applied. Additionally, references cited in study reports which met the inclusion criteria were evaluated. Unpublished manuscripts, reviews, conference abstracts, and non-peer reviewed articles were not considered. The literature search was performed by the author of this dissertation.

3.1 Inclusion criteria

The studies had to fulfil the following inclusion criteria to be included in this systematic review: (1) was published in English language; (2) was published in peer-reviewed journal; (3) included only healthy participants; (4) used bodyweight loading during the intervention; (5) used variations of jump exercises during the intervention; (6) clearly specified intervention volume, intensity, and rest period length; (7) used non-machine based exercises (i.e., sledges, isokinetic dynamometers, or other special equipment); (8) clearly specified how "jumps to fatigue" was determined. Study reports using assisted jumps, resisted jumps, and special equipment such as sledges and isokinetic dynamometers were excluded to reduce the possibility of further confounding variables, to ensure clarity in our review, and to make the results of this review easier to apply in most training settings without the need for special equipment. No restriction related to the outcomes was in place.

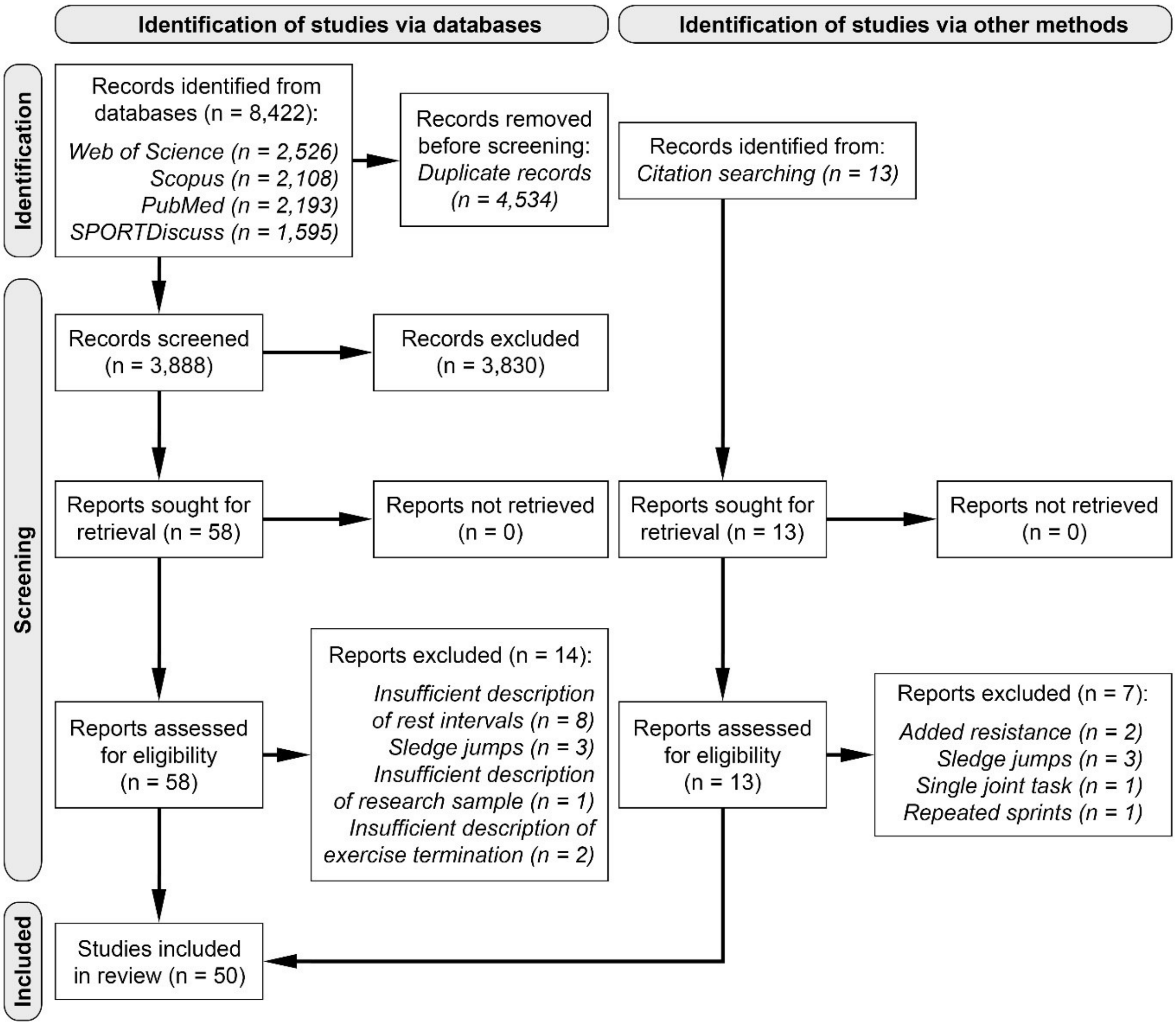
3.2 Study selection and data extraction

The study selection process was initiated by downloading the records and removing duplicates. Titles and abstracts were screened, and any irrelevant records removed. The eligibility of the remaining records was assessed using the full texts. The following information was extracted from the eligible study reports: (1) identification information of the study; (2) sample size; (3) characteristics of participants such as age, gender, and training status; (4) intervention characteristics such as exercise(s) used, volume, intensity, rest duration, and set structure; and (5) relevant outcome measures. Study selection, eligibility assessment, and data extraction were performed by the author of this dissertation. In case of any uncertainty the study selection, assessment, and data extraction were consulted with the supervisor.

3.3 Search results

The literature search of four databases identified a total of 8,422 studies. Fourty-four studies met our inclusion criteria after removing duplicate results and screening for eligibility. Backward citation searching of the eligible studies resulted in identification of another 6 eligible studies. Therefore, a total of 50 studies were included in our review. Figure 1 provides a flow chart of the literature search process.

Figure 1. Flow chart of the literature search process.



3.4 Characteristics of included studies

A total of 1177 participants (1050 males, 83 females, and 44 of unspecified sex) participated in the included studies. Two studies included only female participants (Kamandulis et al., 2019; Ramírez-Campillo et al., 2018), five studies included participants of both sexes (Brown et al., 2010; Ducrocq et al., 2020; Konstantopoulos et al., 2021; Kramer et al., 2019; McNeal et al., 2010), two studies did not specify the sex of participants (Cooper et al., 2020; Tobin & Delahunt, 2014), and the rest of the studies included only male participants. Five studies included only youth participants (Bianchi et al., 2018; Bouguezzi et al., 2020; Ramírez-Campillo et al., 2014, 2015, 2019), two studies included both, young and adult participants (Lazaridis et al., 2018; Marginson et al., 2005), and the rest included only adult participants. Ten studies classified the training status of participants as untrained (Eiras et al., 2009; Lazaridis et al., 2018; Makaruk et al., 2014; Miyama & Nosaka, 2004a, 2004b, 2007; Saez de Villarreal Saez et al., 2008; Skurvydas et al., 2000, 2006, 2018), 15 as physically active (Asadi, 2015; Asadi & Ramírez-Campillo, 2016; Dias et al., 2022; Kamandulis et al., 2019; Konstantopoulos et al., 2021; Kramer et al., 2019; Moreno et al., 2014; Pereira, de Freitas, et al., 2009; Pereira et al., 2014; Pereira, Morse, et al., 2009; Satkunskiene et al., 2021; Skurvydas et al., 2011; Skurvydas, Kamandulis, & Masiulis, 2010; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010; Wadden et al., 2012), 21 as trained (Bianchi et al., 2018; Bouguezzi et al., 2020; Brown et al., 2010; Chatzinikolaou et al., 2010; Z.-R. Chen et al., 2013; Cooper et al., 2020; Dal Pupo et al., 2013; Ducrocq et al., 2020; Fernandes et al., 2020; Hespanhol et al., 2007; Kons et al., 2020; McNeal et al., 2010; Paulus et al., 2021; Pereira et al., 2008; Ramírez-Campillo et al., 2014, 2015, 2018, 2019; Read & Cisar, 2001; Tobin & Delahunt, 2014; Yanci et al., 2017), 2 included participants of multiple training levels (Kamandulis et al., 2016; Skurvydas et al., 2002), and 2 studies did not specify the training status (Ftikas et al., 2010; Marginson et al., 2005). Twenty-six studies used a within-subject design, and 24 studies used a between-subjects design. Table 1 includes an overview of participants characteristics for individual studies. Experimental protocols and assessed outcomes are summarized in Table 2.

Table 2. Characteristics of individual study samples.

Study	**Sample size**	**Sex (n)**	**Age [years]**	**Height [cm]**	**Mass [kg]**	**Training status**
Asadi, 2015	EG1: 7 EG2: 7	M M	20.2 ± 1.1 20.7 ± 1.5	180.5 ± 4.2 180.1 ± 5.5	73.3 ± 7.1 71.7 ± 9.6	Physically active college students familiar with PT, 1RM leg press > 2.5×BW
Asadi et al., 2016	EG1: 6 EG2: 7	M M	20.5 ± 0.6 20.2 ± 0.5	180.1 ± 4.5 179.6 ± 3.2	78.4 ± 3.6 79.2 ± 2.8	Physically active college students familiar with PT
Bianchi et al., 2018	EG1: 10 EG2: 11	M M	17 ± 0.8*	177.4 ± 6.2*	70.1 ± 6.4*	Elite level youth soccer players
Bouguezzi et al., 2020	EG1: 15 EG2: 15	M M	11.32 ± 0.27 12.17 ± 0.33	145.33 ± 3.56 145.18 ± 5.67	39.0 ± 6.08 35.44 ± 4.77	Pre-pubescent soccer players with no regular strength or PT experience
Brown et al., 2010	EG: 20	M (10) F (10)	22.6 ± 1.3 21.4 ± 1.3	175.6 ± 8.0 167.4 ± 7.7	78.9 ± 12.4 65.6 ± 7.3	Recreationally trained (aerobic + resistance 3-5× per week), 1RM leg press > 1.5×BW
Chatzinikolaou et al., 2010	EG: 12 CG: 12	M M	23.1 ± 2.6 25.5 ± 1.9	186 ± 4 184 ± 5	84.2 ± 8.2 82.7 ± 6.1	Trained (aerobic + resistance ≥ 3× per week), 1RM squat ≥ 2×BW
Chen et al., 2013	EG: 10	M	20.9 ± 1.6	178.4 ± 7.4	73.6 ± 10.7	Division I college volleyball players (≥ 3 yrs of volleyball training) familiar with PT
Cooper et al., 2020	EG1: 24	NS	21-28#	166.66 ± 9.20	66.80 ± 11.52	Recreationally trained (exercise ≥ 3× per week)

*1RM = one repetition maximum, BW = bodyweight, CG = control group, EG = experimental group, F = female, M = male, NS = not specified, PT = plyometric training, * combined across all groups, # only range reported.*

Table 2. Continued.

Study	Sample size	Sex (n)	Age [years]	Height [cm]	Mass [kg]	Training status
Dias et al., 2021	EG: 7	M	26.5 ± 4.0	178.4 ± 6.7	80.5 ± 16.9	Physically active (aerobic + resistance 3-4× and ≥ 150 min per week), unaccustomed to
Ducrocq et al., 2020	EG: 13	M (9) F (4)	21.2 ± 1.9	173.1 ± 9.0	67.4 ± 9.4	Trained sport science students (team or racquet sports ≥ 3× per week)
Eiras et al., 2009	EG1: 18 EG2: 18	M M	18.6 ± 0.5 18.8 ± 0.7	177.4 ± 7.9 178.0 ± 6.5	66.5 ± 12.1 68.6 ± 9.2	Untrained
Fernandes et al., 2020	EG: 20	M	20.7 ± 1.1	NS	77.1 ± 11.5	Recreational team sport players not performing systematic lower-body training
Ftikas et al., 2010	EG1: 11 EG2: 11	M M	10.2 ± 0.7 24.3 ± 3.3	147 ± 8 181 ± 5	40 ± 7 81 ± 7	NS
Hespanhol et al., 2007	EG: 10	M	19.01 ± 1.36	191.5 ± 5.36	81.74 ± 7.45	Volleyball players (mean training age = 6 yrs)
Kamandulis et al., 2016	EG1: 10 EG2: 10 EG3: 10 CG: 8	M M M M	24.6 ± 4.81 25.1 ± 4.57 22.3 ± 2.31 22.0 ± 2.45	180.0 ± 5.14 180.8 ± 5.74 183.1 ± 5.78 196.6 ± 8.82	77.2 ± 9.17 77.4 ± 7.09 80.8 ± 13.82 88.4 ± 11.71	EG1-3: Physically active sport science college students (recreational activity 1-3× per week) unaccustomed to PT; CG: national level basketball players

Table 2. Continued.

Study	**Sample size**	**Sex (n)**	**Age [years]**	**Height [cm]**	**Mass [kg]**	**Training status**
Kamandulis et al., 2019	EG: 17	F	20.8 ± 1.4	168.2 ± 5.6	59.5 ± 7.6	Untrained but physically active
Kons et al., 2020	EG: 14	M	22.5 ± 3.6	172.0 ± 8.7	76.5 ± 15.5	Judo athletes (training age 11.8 ± 5.1 yrs, training 3-4× per week)
Konstanto-poulos et al., 2021	EG: 24	M (12) F (12)	22.0 ± 2.0	170 ± 10	67.7 ± 12.3	Physically active college students with no systematic involvement in sporting activities
Kramer et al., 2019	EG: 21	M (13) F (8)	25 ± 4	174 ± 9	73 ± 12	Physically active (mean weekly exercise duration = 5 ± 5 h)
Lazaridis et al., 2018	EG1: 13 EG2: 13	M M	10 ± 0.7 25.3 ± 3.3	147 ± 5 181 ± 4	40.5 ± 6.9 80.0 ± 7.1	Untrained with no systematic participation in sport training
Makaruk et al., 2014	EG1: 12 EG2: 12 CG: 12	M M M	22.2 ± 1.1 22.7 ± 1.4 22.6 ± 1.8	181 ± 6 184 ± 7 182 ± 8	76.8 ± 5.9 77.4 ± 6.2 78.1 ± 6.9	Untrained, physically active (8 h per week) college students with PT experience

Table 2. Continued.

Study	**Sample size**	**Sex (n)**	**Age [years]**	**Height [cm]**	**Mass [kg]**	**Training status**
Marginson et al., 2005	EG1: 10 EG2: 10	M M	9.9 ± 0.3 22.2 ± 2.7	138.2 ± 5.4 183.5 ± 5	32.2 ± 6.3 71.8 ± 6.3	NS
McNeal et al., 2010	EG: 20	M (11) F (9)	21.4 ± 1.6 21.9 ± 3.7	179 ± 9 172 ± 10	78.7 ± 11 75.9 ± 21.4	NCAA Division I athletes (track and field, soccer)
Miyama et al., 2004	EG1: 8 EG2: 8	M M	23.3 ± 3.5*	171.8 ± 5.7*	62.0 ± 7.3*	Students with little or no experience in resistance training
Miyama et al., 2004	EG: 8	M	23.0 ± 3.4	172.2 ± 6.4	62.7 ± 9.3	Little or no resistance training experience
Miyama et al., 2007	EG1: 8 EG2: 8	M M	21.1 ± 1.1*	174.0 ± 7.2*	65.1 ± 8.0*	Untrained - little or no experience in resistance training
Moreno et al., 2014	EG: 26	M	22.32 ± 2.1	178.11 ± 5.89	81.0 ± 9.53	Participating in jumping and lower-body resistance exercise ≥ 1× per week
Paulus et al., 2021	EG: 20	M	23.6 ± 2.3	187.7 ± 6.6	77.5 ± 8.5	Competitive volleyball players (training >4 hours per week for ≥2 yrs)
Pereira et al., 2008	EG: 10	M	21.6 ± 5.3	185 ± 5	77.2 ± 10.6	National level volleyball players (training age = 5.4 ± 2.4 yrs

Table 2. Continued.

Study	Sample size	Sex (n)	Age [years]	Height [cm]	Mass [kg]	Training status
Pereira et al., 2009	EG: 10	M	21.4 ± 2.4	180 ± 1	77.9 ± 5.3	Physically active
Pereira et al., 2009	EG: 11	M	20.7 ± 2.8	185 ± 9	77.1 ± 8.5	Physically active
Pereira et al., 2014	EG: 7	M	23.9 ± 1.8	178 ± 6	74.5 ± 7.7	Recreational volleyball players
Pupo et al., 2013	EG: 20	M	23.3 ± 3.6	184 ± 5.7	81.7 ± 9.4	Competitive college level volleyball and basketball players (≥ 3 yrs of training; 3× per week)
Ramírez-Campillo et al., 2014	EG1: 13 EG2: 14 EG3: 12 CG: 15	M M M M	10.4 ± 2.0 10.4 ± 2.3 10.3 ± 2.3 10.1 ± 2.0	141 ± 10 141 ± 10 142 ± 10 143 ± 10	37.0 ± 7.0 37.2 ± 6.1 38.0 ± 10.0 39.0 ± 9.3	Soccer players (training age > 2 yrs; 2 training sessions per week; 1-2 competitive games per week)
Ramírez-Campillo et al., 2015	EG1: 57 EG2: 54 CG: 55	M M M	14.2 ± 2.2 14.1 ± 2.2 14.0 ± 2.3	158 ± 12.4 159 ± 12.3 160 ± 13.1	50.3 ± 12.1 51.8 ± 12.2 52.1 ± 12.1	Soccer players (training age > 2 yrs; 2 training sessions per week; 1 game per week) with no strength and PT experience
Ramírez-Campillo et al., 2018	EG1: 8 EG2: 8 CG: 7	F F F	22.8 ± 4.3 21.4 ± 2.5 20.1 ± 1.8	158.0 ± 3.0 157.6 ± 4.8 160.1 ± 5.0	54.9 ± 3.7 59.6 ± 8.5 55.3 ± 3.3	Soccer players (training age ≥ 2 yrs; 3 training sessions and 1 game per week) with no systematic PT experience

Table 2. Continued.

Study	Sample size	Sex (n)	Age [years]	Height [cm]	Mass [kg]	Training status
Ramírez-Campillo et al., 2019	EG1: 7 EG2: 7 EG3: 6 EG4: 6	M M M M	10.9 ± 0.8 11.2 ± 1.4 15.0 ± 0.9 15.6 ± 1.3	148 ± 9 149 ± 4 169 ± 5 169 ± 6	42.5 ± 7.9 40.8 ± 4.2 63.6 ± 5.8 63.6 ± 7.2	Soccer players (training age ≥ 2 yrs; 2 training sessions and 1 game per week) with no systematic resistance and PT background
Read et al., 2001	EG: 12	M	25.08 ± 2.43	174.24 ± 6.28	82.13 ± 10.36	Recreational weightlifters (training age ≥ 1 yr, 1RM squat ≥ 1.5×BW, 1RM leg press ≥ 2×BW)
Saez de Villarreal Saez et al., 2008	EG1: 10 EG2: 12 EG3: 10 CG: 10	M M M M	22.4 ± 1.1 23.1 ± 3.1 21.8 ± 1.3 23.6 ± 2.7	174.7 ± 7.2 176.6 ± 4.9 175.5 ± 4.4 180.3 ± 3.6	75.60 ± 5.4 80.10 ± 9.1 72.68 ± 7.4 78.56 ± 6.2	Physical education students with no regular resistance training or competitive sports and no PT experience
Satkunskiene et al., 2021	EG: 10	M	29.8 ± 9.3	181 ± 7	81.7 ± 5.8	Recreationally active
Skurvydas et al., 2000	EG: 12 CG: 7	M M	25.4 ± 1.7 23.7 ± 2.3	NS NS	74.3 ± 6.2 76.9 ± 4.3	Untrained, physically active not participating in any formal exercise or sport
Skurvydas et al., 2002	EG1: 12 EG2: 10 EG3: 9	M M M	25.4 ± 1.7 24.4 ± 2.5 23.4 ± 2.7	NS NS NS	74.3 ± 6.2 68.3 ± 5.2 74.3 ± 6.2	Untrained Elite long-distance runners Elite sprinters
Skurvydas et al., 2006	EG: 20	M	20.4 ± 1.7	180.7 ± 6.5	76.2 ± 4.7	Untrained, physically active not participating in any formal exercise or sport

Table 2. Continued.

Study	**Sample size**	**Sex (n)**	**Age [years]**	**Height [cm]**	**Mass [kg]**	**Training status**
Skurvydas et al., 2010	EG: 10	M	21.1 ± 1.4	178.7 ± 4.5	75.2 ± 4.1	Physically active students unaccustomed to lower body resistance or PT
Skurvydas et al., 2010	EG: 11	M	20.8 ± 1.2	181.7 ± 6.9	78.2 ± 6.7	Untrained, physically active not participating in any formal exercise or sport
Skurvydas et al., 2011	EG1: 13 EG2: 13	M M	23.8 ± 3.2 22.5 ± 3.9	179.9 ± 3.6 176.9 ± 4.9	77.2 ± 4.5 79.8 ± 3.5	Untrained, physically active
Skurvydas et al., 2018	EG1: 10 EG2: 10 EG3: 10	M M M	19–24*#	179.9 ± 3.6*	77.2 ± 4.5*	Untrained
Tobin et al., 2014	EG: 20	NS	22.4 ± 3.4	184 ± 7	101.2 ± 11.9	Professional rugby union players with ≥ 1 yr of PT experience
Wadden et al., 2012	EG: 14	M	25.3 ± 3.4	179.6 ± 5.3	84.0 ± 10.7	Physically active ≥ 3× per week
Yanci et al., 2017	EG1: 15 EG2: 12 CG: 12	M M M	22.5 ± 5.0*	170 ± 10 180 ± 10 180 ± 10	71.1 ± 8.6 71.7 ± 11.6 65.1 ± 8.6	Amateur national level futsal players (futsal training ≥ 6 months, strength training ≥ 2 yrs, 2-3 training sessions and 1 game per week)

Table 3. Experimental interventions and outcomes of the included studies.

Study	Experimental protocol	Outcome assessment
Asadi, 2015	6 weeks PT; 2 sessions/wk, 48 h (EG1) or 72 h IDR (EG2); PT = 5 × 20 DJs from 45 cm; sand surface; 8 s IRR, 2 min ISR	CMJ with arm swing, standing long jump, agility T test, 20 and 40 m sprint, 1RM leg press
Asadi et al., 2016	6 weeks PT; 2 sessions/wk, 72–96 h IDR; PT = 5 × 20 DJs from 45 cm, 2 min ISR (EG1) or 5 × 2 × 10 DJs from 45 cm, 90 s ISR, 30 s rest between clusters (EG2)	CMJ, standing long jump, agility T test, 20 and 40 m sprint
Bianchi et al., 2018	8 weeks PT; 1 (EG1) or 2 (EG2) session/wk, 48 h IDR (volume not equalized); PT = 4 × 5 DJs with 2 jumps over 15 cm hurdle + 4 × 6 horizontal jumps + 4 × 6 jumps over 15 cm hurdle + 3 x 3 short shuttle runs	Standing long jump, single-leg triple hop distance test, 10, 30, and 40 m sprint, 505 agility test
Bouguezzi et al., 2020	8 weeks PT; 1 (EG1) or 2 (EG2) sessions/wk, 72 h IDR (volume equalized); PT = continuous CMJ + horizontal ankle hops + zig-zag jumps (weekly increased training volume 50–120 foot contacts); 90 s ISR, 90 s rest between exercises	5, 10, 20, and 30 m sprint, agility T test, modified Illinois change of direction test, standing long jump, CMJ, squat jump, reactive strength index, kicking distance
Brown et al., 2010	10 × 8 DJs from 80 cm, 3 min ISR	Heart rate, blood lactate concentration, blood pressure, oxygen uptake, rating of perceived exertion

CG = control group, CMJ = countermovement jump, DJ = drop jump, EG = experimental group, IRR = inter-repetition rest, ISR = inter-set rest, IDR = inter-day rest, MVIC = maximal voluntary isometric contraction, PT = plyometric training.

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Chatzinikolaou et al., 2010	5 × 10 jumps over 50 cm hurdle + 5 × 10 DJs from 50 cm, 2 min ISR, 5 min rest between exercises	CMJ, squat jump, knee extension MVIC (80° knee angle), isokinetic knee extension (60 and 180°·s−1), muscle soreness, knee range of motion, leukocyte count, cytokinesis IL-6 and IL-1b, creatine kinase activity, lactate dehydrogenase, C-reactive protein, uric acid, cortisol, testosterone
Chen et al., 2013	2 conditions: A) 1 × 5, B) 2 × 5 DJs from individualized height (best reactive strength index), 1 min ISR; 24 h IDR	CMJ
Cooper et al., 2020	60 s of continuous CMJs with countermovement to 90° knee angle	Static bilateral and dynamic unilateral balance test, CMJ with arm swing, squat jump
Dal Pupo et al., 2013	30 s of continuous CMJs with countermovement to 90° knee angle	Maximum knee and hip flexion angle, jump height, power output, contact time, vertical stiffness, fatigue index, blood lactate
Dias et al., 2021	5 × 20 DJs from 50 cm with countermovement to 90° knee angle, 2 min ISR; 14 days IDR	Serum concentration of chemical elements (P, S, Cl, K, Ca, Fe, Cu, Zn, Br), creatine kinase activity, muscle soreness, CMJ, squat jump
Ducrocq et al., 2020	3 conditions: A) 22 × 15 s of running at 120 % of maximal oxygen uptake velocity, B) 22 × 15 s of DJs from individualized height (highest power output = 45 ± 12 cm) at jump frequency of 7 jumps per 15 s, C) same as condition B except jump frequency of 9 jumps per 15 s; 15 s ISR	Ventilatory gas exchange parameters, MVIC and electrically induced (1, 10, and 100 Hz) knee extension (135° hip angle, 90° knee angle), EMG (vastus lateralis, vastus medialis, rectus femoris), heart rate, blood lactate concentration, and rating of perceived exertion

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Eiras et al., 2009	4 × 10 DJs from 30 cm, 60 s (EG1) or 180 s (EG2) ISR	Creatine kinase activity, muscle soreness
Fernandes et al., 2020	10 × 10 continuous CMJs with countermovement to 90° knee angle, 60 s ISR	Isokinetic knee extension (60 and 240°·s−1), CMJ, creatine kinase activity, muscle soreness
Ftikas et al., 2010	10 × 10 continuous CMJs, 30 s ISR	DJ with hand on hips from 30 cm, knee extension MVIC (110° knee angle)
Hespanhol et al., 2007	2 conditions: A) 60 s continuous CMJs, B) 4 × 15 s continuous CMJs, 10 s ISR; 7 days IDR	Jump height, number of jumps, fatigue index, peak and mean power output
Kamandulis et al., 2016	Cycling test starting at 100 W with 5 W increase every 10 s to volitional failure at 70 rpm (EG1); 70 DJs from 50 cm with countermovement to 90° knee angle, 30 s IRR (EG2); remaining sleepless for 24 h (EG3); 6 weeks monitoring (CG)	Knee extension MVIC (110° knee angle), CMJ, creatine kinase activity, power at the time of cycling exhaustion, blood lactate, muscle soreness, speed of information processing, emotional state
Kamandulis et al., 2019	100 DJs with arms on hips from 40 cm with countermovement to 90° knee angle, 20 s IRR; repeated after 28 days IDR	MVIC and electrically induced (20 and 100 Hz) knee extension (110° knee angle), and muscle soreness
Kons et al., 2020	10 × 10 continuous CMJs with countermovement to 90° knee angle, 60 s ISR	Bilateral asymmetry index based on unilateral CMJ, rating of perceived exertion, muscle soreness

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Konstantopoulos et al., 2021	5 × 20 continuous unilateral CMJs, 30 s ISR	Jump height, hip adduction, hip abduction, internal hip rotation and external hip rotation MVIC, Y-balance test, stance phase of gait
Kramer et al., 2019	5 conditions: ~180 CMJs in 5, 9, or 12 sets of 40 s with 0, 15, or 30 s ISR and 0, 1, or 2 s IRR (0-0, 30-0, 15-1, 30-1, 30-2)	Oxygen uptake, heart rate, jump height, ground reaction force, rating of perceived exertion, blood lactate
Lazaridis et al., 2018	10 × 10 continuous CMJs, 30 s ISR	Knee extension MVIC (110° knee angle), DJ from 30 cm, EMG (vastus lateralis, vastus medialis, soleus), jump height, ground reaction force, peak power output, contact time
Makaruk et al., 2014	6 weeks of PT; 3 sessions/wk, 48 h IDR; PT = 1 horizontal + 3 vertical exercises, 4–8 × 3 repetitions, 4–5 s IRR (EG1), continuously (EG2), or no PT (CG); PT intensity increased weekly	CMJ, 3 consecutive CMJs, DJ from 60 cm
Marginson et al., 2005	8 × 10 continuous CMJs with countermovement to 90° knee angle, 1 min ISR, repeated after 14 days IDR	Knee extension MVIC (80°, 90°, 100°, 120°, 140°, and 160° knee angle), CMJ, squat jump, muscle soreness
McNeal et al., 2010	60 s continuous CMJs with countermovement to 90° knee angle	Ground reaction forces, contact time, flight time, EMG (tibialis anterior, gastrocnemius, biceps femoris, vastus lateralis), movement kinematics

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Miyama et al., 2004	5 × 20 DJs from 60 cm, 10 s IRR, 2 min ISR; sand (EG1) wooden (EG2) surface	Ground reaction forces, contact time, jump height, squat jump, CMJ, knee extension MVIC (90° knee angle), muscle soreness, creatine kinase activity
Miyama et al., 2004	5 × 20 DJs from 60 cm, 10 s IRR, 2 min ISR; 8 days IDR	Ground reaction forces, contact time, jump height, squat jump, CMJ, knee extension MVIC (90° knee angle), muscle soreness, creatine kinase activity
Miyama et al., 2007	10 DJs from 60 cm followed by 5 × 10 DJs, 14 days IDR (EG1); 5 × 10 DJs from 60 cm, repeated after 14 days IDR (EG2); 10 s IRR, 1 min ISR	CMJ, squat jump, MVIC (110° knee angle) and isokinetic knee extension (90, 180, and 300°·s−1), muscle soreness, creatine kinase activity, jump height, contact time, ground reaction force, heart rate, blood lactate
Moreno et al., 2014	3 conditions: A) 2 × 10 CMJs, 90 s ISR, B) 4 × 5 CMJs, 30 s ISR, C) 10 × 2 CMJs, 10 s ISR; 7 days IDR	Power output, ground reaction force, take-off velocity, jump height
Paulus et al., 2021	50 CMJs at rate of 33 jumps per minute; 7 days IDR	Jump height
Pereira et al., 2008	5 conditions: A) Volleyball spikes to failure (3 consecutive jumps below target height), 4 s IRR, B-E) 30 maximal volleyball spikes with 8, 14, 17, 20 s IRR followed by volleyball spikes to failure	Heart rate, blood lactate
Pereira et al., 2009	4 conditions: CMJs to failure (3 consecutive jumps below target height), A) 4.1 ± 0.3, B) 5.0 ± 0.4, C) 5.9 ± 0.6 and D) 7.5 ± 1.6 s IRR	Number of jumps, time to exhaustion, total work

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Pereira et al., 2009	3 conditions: CMJs to failure (3 consecutive jumps below target height), ~6 ± ~2 s IRR; A) short condition (~10 min, ~100 jumps), B) long condition (~25 min, ~200 jumps), and C) control condition (10 min of passive rest)	Knee extension MVIC, knee flexion MVIC (90° knee angle), voluntary knee extension activation level, M-wave of quadriceps femoris
Pereira et al., 2014	CMJs to failure (3 consecutive jumps below target height), 7.4 ± 1.6 s IRR (6 ± ~2 s)	Segment angular displacement (shank, thigh, trunk) at the amortization phase of countermovement, intersegmental coordination, take-off velocity, and jump height
Ramírez-Campillo et al., 2014	7 weeks PT; 2 sessions/wk, 48 h IDR; PT = 2 × 10 DJs from 20, 40, and 60 cm; 15 s IRR, 30 (EG1), 60 (EG2), 120 s (EG3) ISR, or no PT (CG)	CMJ, reactive strength index during DJ from 20 and 40 cm, maximal kicking distance, 20 m sprint, agility L test
Ramírez-Campillo et al., 2015	6 weeks PT; 2 sessions/wk, 24 (EG1), 48 h IDR (EG2), or no PT (CG); PT = 2 × 5–10 repetitions of 13 plyometric exercises per session (weekly increasing PT volume 140–260 foot contacts per session), 120 s ISR, 0 or 15 s IRR	CMJ, squat jump, reactive strength index during DJ from 20 cm, standing long jump, 20 m sprint, 10×5 m agility test, 20 m multistage shuttle run test, sit-and-reach test
Ramírez-Campillo et al., 2018	8 weeks PT; 1 (EG1) or 2 sessions/wk (EG2), (equalized PT volume); PT = 5 exercises each for 14–28 (EG1) or 7–14 repetition (EG2) per session; 0–15 s IRR, 30–60 s ISR; no PT (CG)	CMJ, DJ from 20 cm, maximal kicking velocity, 15 m sprint, Meylan change of direction ability test, Yo-Yo intermittent recovery endurance test level 1
Ramírez-Campillo et al., 2019	8 weeks PT; 2 sessions/wk; PT = 6 exercises each for 2 × 4–8 (weekly increasing volume); 0–3 s IRR, 30 and 120 s ISR (cross-over design); EG1 and EG3 started with 30 s ISR	CMJ with arm swing, standing long jump, DJ from 20 cm

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Read et al., 2001	3 conditions: 10 DJs from individualized height (61.67 ± 16.42 cm); A) 15 s, B) 30 s, and C) 60 s IRR; 24 h IDR	JH and mean propulsion GRF
Saez de Villarreal Saez et al., 2008	7 weeks PT; 1 (EG1), 2 (EG2), 3 sessions/wk (EG3), or no PT (CG) (not equalized PT volume); PT = 2×10 DJ from 20, 40 and 60 cm, respectively; 60 s ISR	CMJ, DJ from 20, 40, and 60 cm, 1RM leg press, leg press MVIC, 20 m sprint
Satkunskiene et al., 2021	4 × 50 DJs from 50 cm with countermovement to 90° knee angle; 30 s IRR, 20 min. ISR	CMJ, MVIC and electrically induced (20 and 100 Hz) knee extension (110° knee angle), muscle soreness, creatine kinase activity
Skurvydas et al., 2000	100 DJs from 40 cm with countermovement to 90° knee angle, 20 s IRR and 5 × 20 continuous CMJs with countermovement to 90° knee angle, 10 s ISR; 8 weeks IDR (EG); same intervention in reversed order (CG)	CMJ, squat jump, MVIC and electrically induced (1,10, 15, 20, and 50 Hz) knee extension (semi-flexed knee position),
Skurvydas et al., 2002	100 DJs from 40 cm with countermovement to 90° knee angle, 20 s IRR	CMJ, squat jump, DJ form 40 cm with countermovement to 90 and 135° knee angle, MVIC and electrically induced (20 and 50 Hz) knee extension (90° knee angle), muscle soreness
Skurvydas et al., 2006	100 DJs from 75 cm with countermovement to 90° knee angle, 20 s IRR	DJ from 75 cm, MVIC and electrically induced (20 and 50 Hz) knee extension (90° and 135° knee angle), creatine kinase activity, muscle soreness
Skurvydas et al., 2010	2 × 50 continuous CMJs with countermovement to 90° knee angle, 60 min. ISR	MVIC and electrically induced (15 and 50 Hz) knee extension (90° knee angle), CMJ, blood lactate, creatine kinase activity, muscle soreness

Table 3. Continued.

Study	Experimental protocol	Outcome assessment
Skurvydas et al., 2010	5 × 20 CMJ with countermovement to 90° knee angle, 10 s ISR; repeated 4 times with 72 h IDR	MVIC and electrically induced (20 and 100 Hz) knee extension (90° knee angle), CMJ performance with countermovement to 90° knee angle, blood lactate, creatine kinase activity
Skurvydas et al., 2011	50 (EG1) and 100 (EG2) DJs from 50 cm with countermovement to 90° knee angle, 30 s IRR	DJ from 50 cm with countermovement to 90° knee angle, MVIC and electrically induced (20 and 100 Hz) knee extension (110° knee angle), isokinetic knee extension (30°·s−1 at 70-150° knee angle), creatine kinase activity, muscle soreness
Skurvydas et al., 2018	50 (EG1), 100 (EG2), and 200 (EG3) DJs from 50 cm with countermovement to 90° knee angle, 30 s IRR	DJ from 50 cm with countermovement to 90° knee angle, MVIC and electrically induced (20 and 100 Hz) knee extension (110° knee angle), creatine kinase activity, muscle soreness
Tobin et al., 2014	2 × 10 ankle hops + 3 × 5 hurdle hops (70 cm) + 3 × 5 DJs from 50 cm, 30 s ISR, 15 s IRR (only DJ)	CMJ
Wadden et al., 2012	3 conditions: A) continuous DJs from 30 cm to failure (inability to keep the set pace) at 35 jumps·min−1, B) barbell back squat to 90° knee angle with 65% 1RM to failure at 15 squats·min-1, C) passive rest	MVIC and electrically induced knee extension (90° knee angle), heart rate, blood lactate
Yanci et al., 2017	6 weeks PT; 1 (EG1), 2 sessions/wk (EG2), or no PT (CG); equalized PT volume (91–176 weekly foot contacts); PT = 9 horizontal, vertical, and lateral plyometric exercises per PT session	5 and 15 m sprint, 505 agility test, repeated sprint ability, CMJ (bilateral and unilateral), standing long jump (bilateral and unilateral)

3.5 Risk of bias assessment

Cochrane Collaboration's tools were used to assess the risk of bias in the included studies. Specifically RoB 2.0 for randomized trials, RoB 2.0 for cluster-randomized trials, RoB 2.0 for crossover trials (Sterne et al., 2019), and ROBINS-I (Sterne et al., 2016) were used according to the research design of each study. The risk of bias assessment was performed by the author of this dissertation. In case of uncertain judgements, the final decision was made after consultation with the supervisor. An important consideration for interpreting the assessment results was the difference in judgement scales between RoB 2.0 and ROBINS-I. ROBINS-I tool allows for domain judgement of "not included" when the information to answer the relevant signaling questions are insufficient or missing. On the other hand, this domain judgement is not possible for RoB 2.0 tool and such situations often result in "high risk of bias" judgement. Therefore, when discussing the results of the included studies, a distinction was made between the studies that were assessed to include high risk of bias due to included or missing information. It is likely that many of these issues were present because of underreporting, as opposed to flawed research design.

According to the design of individual studies, 15 studies were assessed using RoB 2.0 tool for randomized trials, 1 using RoB 2.0 tool for cluster-randomized trials, 10 using RoB 2.0 tool for crossover trials, and 24 using ROBINS-I tool. Out of the 26 studies assessed for bias due to randomization process, only one was judged as low risk (Ramírez-Campillo et al., 2018), while the rest included some concerns, those are mostly due to missing details about concealing the allocation sequence or randomization method. Bias due to period and carryover effects was specific only for crossover studies, some concerns existed for 2 studies (Ducrocq et al., 2020; Moreno et al., 2014). Five studies were considered high risk for bias due to deviations from intended interventions. Reasons were missing information about the implementation and/or adherence to the intervention (Asadi & Ramírez-Campillo, 2016; Makaruk et al., 2014; Saez de Villarreal Saez et al., 2008), and concerns regarding control of important non-protocol interventions (Skurvydas et al., 2011, 2018). High risk of bias due to missing outcome data was present for 20 studies, and insufficient information was reported by 17 studies. However, the reason for the high risk in all cases was the inability to confirm that the data were available for all or nearly all participants, based on the reported information. Some concerns regarding measurement of the outcome existed only for one study (Chatzinikolaou et al., 2010). This was due to the assessment of muscle soreness as a subjective rating during muscle compression while both participants and outcome assessors were potentially aware of the intervention received. Other studies which included this method also included other muscle soreness assessments (i.e., during squatting or walking without compression). Some concerns for risk of bias due to selection of the reported result was present in all included studies as analysis according to a prespecified plan could not be confirmed for any included study. Three domains were assessed only for non-randomized studies: confounding, selection of participants, and classification of interventions. Six studies were classified as serious risk of bias due to confounding caused by intervention order (Hespanhol et al., 2007), not controlling for physical activity before intervention (Kamandulis et al., 2016, 2019; Marginson et al., 2005; Skurvydas et al., 2006), missing information about training status and sport specialization (Fernandes et al., 2020), and possible training effect resulting from the knee extension testing (Kamandulis et al., 2019). The risks of bias in selection of participants and classification of interventions were low for all non-randomized studies. The full risk of bias assessment report is presented in Tables 3 and 4.

Table 4. Risk of bias assessments of randomized designs.

Study	D1	D1b	DS	D2a	D2b	D3	D4	D5
Asadi 2015 ^{a}	−	NA	NA	−	+	×	+	−
Asadi et al. 2016 ^{a}	−	NA	NA	−	×	×	+	−
Bianchi et al. 2018 ^{a}	−	NA	NA	−	+	+	+	−
Bouguezzi et al. 2020 ^{a}	−	NA	NA	−	+	+	+	−
Chatzinikolaou et al. 2010 ^{a}	−	NA	NA	−	+	×	−	−
Chen et al. 2013 ^{b}	−	NA	+	−	+	×	+	−
Ducrocq et al. 2020 ^{b}	−	NA	−	−	+	×	+	−
Eiras et al. 2009 ^{a}	−	NA	NA	−	+	×	+	−
Kramer et al. 2019 ^{b}	−	NA	+	−	−	×	+	−
Makaruk et al. 2014 ^{a}	−	NA	NA	−	×	×	+	−
Miyama et al. 2004 ^{a}	−	NA	NA	−	+	×	+	−
Miyama et al. 2007 ^{a}	−	NA	NA	−	+	×	+	−
Moreno et al. 2014 ^{b}	−	NA	−	−	+	×	+	−
Pereira et al. 2008 ^{b}	−	NA	+	−	+	×	+	−
Pereira et al. 2009 ^{b}	−	NA	+	−	+	×	+	−
Pereira et al. 2009 ^{b}	−	NA	+	−	−	×	+	−
Ramírez-Campillo et al. 2014 ^{a}	−	NA	NA	−	+	+	+	−
Ramírez-Campillo et al. 2015 ^{a}	−	NA	NA	+	+	+	+	−
Ramírez-Campillo et al. 2018 ^{a}	+	NA	NA	+	+	+	+	−
Ramírez-Campillo et al. 2019 ^{b}	−	NA	+	+	+	+	+	−
Read et al. 2001 ^{b}	−	NA	+	−	+	×	+	−
Saez de Villarreal Saez et al. 2008 ^{a}	−	NA	NA	−	×	×	+	−
Skurvydas et al. 2011 ^{a}	−	NA	NA	−	×	×	+	−
Skurvydas et al. 2018 ^{a}	−	NA	NA	−	×	×	+	−
Wadden et al. 2012 ^{b}	−	NA	+	−	+	×	+	−
Yanci et al. 2017 ^{c}	−	+	NA	+	+	×	+	−

D1 = Randomization process, D1b = Timing of identification and recruitment of individual participants in relation to timing of randomization, DS = Period and carryover effects, D2a = Deviations from intended intervention: effect of assignment to intervention, D2b = Deviations from intended intervention: effect of adhering to intervention, D3 = Missing outcome data, D4 = Measurement of the outcome, D5 = Selection of the reported result, × = High risk of bias, − = Some concerns, + = Low risk of bias, NA = Not applicable, a = RoB 2.0 for randomized trials, b = RoB 2.0 for crossover trials, c = RoB 2.0 for cluster-randomized trials.

Table 5. Risk of bias assessment of non-randomized designs.

Study	D1	D2	D3	D4	D5	D6	D7
Brown et al. 2010	+	+	+	+	+	+	?
Cooper et al. 2020	+	+	+	+	?	+	?
Dal Pupo et al. 2013	+	+	+	+	?	+	?
Dias et al. 2021	+	+	+	+	+	+	?
Fernandes et al. 2020	×	+	+	+	?	+	?
Fitkas et al. 2010	+	+	+	+	?	+	?
Hespanhol et al. 2007	×	+	+	+	+	+	?
Kamandulis et al. 2016	×	+	+	+	?	+	?
Kamandulis et al. 2019	×	+	+	+	+	+	?
Kons et al. 2020	+	+	+	+	+	+	?
Konstantopoulos et al. 2021	+	+	+	+	?	+	?
Lazaridis et al. 2018	+	+	+	+	?	+	?
Marginson et al. 2005	×	+	+	+	?	+	?
McNeal et al. 2010	+	+	+	+	?	+	?
Miyama et al. 2004	+	+	+	+	?	+	?
Paulus et al. 2021	+	+	+	+	?	+	?
Pereira et al. 2014	+	+	+	+	?	+	?
Satkunskiene et al. 2021	+	+	+	+	?	+	?
Skurvydas et al. 2000	−	+	+	+	?	+	?
Skurvydas et al. 2002	+	+	+	+	?	+	?
Skurvydas et al. 2006	×	+	+	+	?	+	?
Skurvydas et al. 2010	+	+	+	+	+	+	?
Skurvydas et al. 2010	+	+	+	+	?	+	?
Tobin et al. 2014	+	+	+	+	+	+	?

D1 = Confounding, D2 = Selection of participants, D3 = Classification of interventions, D4 = Deviations from intended intervention, D5 = Missing data, D6 = Measurement of outcomes, D7 = Selection of the reported result, ! = Critical risk of bias, × = Serious risk of bias, − = Moderate risk of bias, + = Low risk of bias, ? = No information.

3.6 Athlete characteristics

Prescribing plyometric training, rest periods included, requires many factors to be considered, some of which are related to the characteristics of an athlete for whom the training program is intended. Gender might be one such factors, although current plyometric literature focused on rest duration and fatigue includes mainly male participants. Nevertheless, our literature search identified five studies that included participants of both genders (Brown et al., 2010; Ducrocq et al., 2020; Konstantopoulos et al., 2021; Kramer et al., 2019; McNeal et al., 2010). One of them reported no time × gender interaction for contact time, flight time, peak eccentric force, time to peak concentric force, and muscle activation (McNeal et al., 2010). Another one observed no significant gender-related differences in oxygen uptake, heart rate, and blood lactate concentration (Brown et al., 2010). The other three studies did not report any data addressing the interaction between genders and plyometric exercise (Ducrocq et al., 2020; Konstantopoulos et al., 2021; Kramer et al., 2019), presumably because there were no differences. On the other hand, although the current evidence shows that gender does not seem to affect plyometric performance, we are not comfortable making such a generalization based on only two studies that were performed under very specific conditions. Considering the negative effects of fatigue on motor control (Chappell et al., 2005) combined with the wealth of literature indicating greater injury risk in the lower limbs of females (Gornitzky et al., 2016; Montalvo et al., 2019; Prodromos et al., 2007), future research should be conducted to directly compare the effects of gender on plyometric jump performance.

Age, on the other hand, seems to influence fatiguability during plyometric exercise (Ftikas et al., 2010; Lazaridis et al., 2018; Marginson et al., 2005). Studies including fatiguing plyometric protocols of 10 (Ftikas et al., 2010; Lazaridis et al., 2018) and 8 (Marginson et al., 2005) sets of 10 consecutive CMJs with 30- (Ftikas et al., 2010; Lazaridis et al., 2018) and 60-seconds (Marginson et al., 2005) of inter-set rest concluded that jumping performance in pre-pubescent boys was impacted significantly less than in adult men. Authors of these studies hypothesized that this could be a result of lower muscle mass (Lazaridis et al., 2018), more compliant musculotendinous tissue (Ftikas et al., 2010; Lazaridis et al., 2018; Marginson et al., 2005), a higher distribution of slow type motor units (Ftikas et al., 2010; Lazaridis et al., 2018; Marginson et al., 2005), less strain per muscle fiber resulting from lower power output relative to body mass (Marginson et al., 2005), or higher levels of habitual activity which includes hopping and jumping tasks and therefore greater adaption to plyometric exercise (Marginson et al., 2005) in pre-pubescent children compared to adults. Furthermore, one study (Ramírez-

Campillo et al., 2019) compared the effects of plyometric training with either 30- or 120-seconds of inter-set rest across 6 weeks with 2 sessions per week in pre- and post-peak height velocity (~11 and ~15 years old, respectively) male soccer players. There were no significant differences between long and short inter-set rest periods in the younger group. However, the older group showed significantly greater improvements in all tests when using longer inter-set rest durations. Although the evidence supports the notion that children are less fatigable than adults and have greater habitual activity that includes hopping and jumping, children are not "bullet-proof", and correct jumping and landing techniques should always be at the forefront of plyometric training in children, all while progressing training volume and intensity at appropriate levels that do not exceed the abilities of the individual (Johnson et al., 2011; Lloyd et al., 2014). On the other hand, considering the fairly intense nature of plyometric training, the same can be said of jumping technique, landing technique, and progression for adults, especially those who are untrained.

Also training status seems to be an important factor influencing the amount of fatigue accumulated during plyometric exercise. For example, elite long-distance runners, elite sprinters, and untrained individuals differed in their response to a single fatiguing plyometric protocol including 100 DJs from 40 cm with 20 seconds of inter-repetition rest (Skurvydas et al., 2002). Although jumping performance, voluntary knee extension torque, and electrically induced knee extension torque all significantly decreased immediately after the plyometric session in all groups, the electrically induced knee extension torque decreased more in the untrained participants, indicating greater peripheral fatigue compared to their trained counterparts. Additionally, CMJ and DJ performance decreased less in sprinters compared to both untrained participants and long-distance runners, which suggests that beside the training status, also training specificity should be considered when creating the plyometric training program. In this case, the drop height might be an important factor in explaining the difference between the trained groups. Regular exposure to higher velocities and accelerations during sprinting would probably be more related to the performed task. In another study a low-volume plyometric session of 10 DJs from 60 cm with 10 seconds of inter-repetition rest caused significant decrease of subsequent jump height in untrained participants (Miyama & Nosaka, 2007), but the same volume of DJs increased jump height of elite male volleyball players, thereby having a potentiating effect (Z.-R. Chen et al., 2013). Although, we need to be careful when comparing these studies as the later used individualized drop height of either 20, 40, or 60 cm, determined as the height producing most favorable reactive strength index. Similarly, plyometric session including 50 rebound jumps caused performance potentiation in plyometrically experienced professional rugby players (Tobin & Delahunt, 2014) but decreased jumping performance in untrained men (Miyama & Nosaka, 2007). In line with these results, another study reported that highly trained men were able to sustain submaximal continuous DJs from 30 cm for significantly longer time than moderately trained men (Wadden et al., 2012). However, the highly trained group involved only 4 participants. Nevertheless, training status and training specificity should be considered when interpreting plyometric research as well as when designing a plyometric training program.

3.7 Within session considerations

Previous paragraphs outlined how athlete characteristics may influence programing decisions for plyometric training. Furthermore, rest periods in relation to the rest of the programing variables seem to notably influence jumping performance. It is important to note that not all exercise interventions used in research are practically applicable in training. Some interventions are designed to mimic actual plyometric programs, but other interventions are designed with the intention to study the effects of fatigue and muscle damage caused using intense plyometric exercises. Although we need to be cautious when interpreting the results of these studies, they could help us understand how athletes react to extreme interplays of volume, intensity, and rest periods when performing these tasks. One example of such fatiguing protocols often used in research is 60 seconds of continuous CMJs, which has been shown to cause significant decrease of multiple performance variables in recreationally trained adults (Cooper et al., 2020), competitive adult volleyball players (Hespanhol et al., 2007), and elite collegiate athletes (McNeal et al., 2010). In fact, elite collegiate athletes were not able to sustain high level performance after only 20 seconds (McNeal et al., 2010). As such, precisely manipulated rest periods could serve as a valuable tool for preventing detrimental effects of fatigue when performing higher volumes of intense plyometric exercises.

Inter-repetition rest seems to play an important role in the amount of acute fatigue resulting from plyometric exercise. Physically active adults experienced significantly decreased peak and average relative oxygen uptake, time above 90% of maximal oxygen uptake, average respiratory exchange rate, blood lactate concentration, and perceived exertion, as well as increased mean jump height normalized to maximal jump height as a result of increased inter-repetition rest from 0- to 1-, and 2-seconds during fatiguing sets of repeated CMJs (Kramer et al., 2019). Additionally, increasing the inter-repetition rest by ~1-2 seconds in range of ~4 to ~8 seconds allowed physically active adults to perform significantly more CMJs to failure, defined as inability to reach 95% of maximal jump height in 3 consecutive repetitions (Pereira, de Freitas, et al., 2009; Pereira, Morse, et al., 2009). However, another study showed that intermittent jumps to failure with 7.4 ± 1.6 s of inter-repetition rest led to significant decrease of jump height and increase of contact time already half-way (~ 40 jumps) through the intervention (Pereira et al., 2014). Collectively, these results suggest that including even extremely short inter-repetition rest might significantly decrease acute fatigue resulting from a single bout of plyometric exercise if the inter-repetition rest is ≤ 8 seconds. Currently, only a single study investigated a chronic effects of plyometric training performed either continuously or with 4-5 seconds of inter-repetition rest in active men, but the results showed no differences in performance improvements between the two conditions (Makaruk et al., 2014). The training program in this study lasted 6 weeks and included 3 training sessions per week. The training volume was equated between the two conditions and the exercise intensity was increased every week. However, it is important to note that 4 exercises per session were performed, each for 4-8 sets of 3 repetitions with 1-2 minutes of inter-set rest. As the applied work-to-rest ratio was relatively modest, we would not expect this training program to cause significant fatigue. As such, increased inter-repetition rest might be more valuable in plyometric programs with higher physical demand. Similarly, the body of literature does not show acute benefits with longer (≥14 s) inter-repetition rest durations in trained individuals. For example, a set of 30 volleyball spikes with 8 seconds of inter-repetition rest caused significant fatigue in experienced adult volleyball players, but inter-repetition rest of 14, 17, and 20 seconds did not (Pereira et al., 2008). Also, recreational adult weightlifters did not experience any significant changes of jump height and vertical ground reaction forces as a result of completing 10 maximal DJs from individualized height (~60 cm) with 15 seconds of inter-repetition rest (Read & Cisar, 2001). However, both studies used low exercise volume and trained participants which prevents generalization of these results.

Inter-set rest is another variable with a potential to influence fatigue resulting from plyometric exercise. Longer inter-set rest intervals (0-, 15-, and 30-seconds) during a volume equated (~180 jumps) plyometric session of repeated maximal effort CMJs significantly increased mean jump height and decreased peak oxygen uptake, average oxygen uptake, time above 90% of maximal oxygen uptake, peak heart rate, and average heart rate in active adults (Kramer et al., 2019). But inter-set rest duration did not seem to affect the speed of recovery assessed via average oxygen uptake and average heart rate measured after the cessation of the plyometric exercise (Kramer et al., 2019). Furthermore, no significant differences were observed in serum creatine kinase activity and muscle soreness after the intervention including 4 sets of 10 DJs from 30 cm with either 60- or 180-seconds of inter-set rest in untrained men (Eiras et al., 2009). Therefore, the most important use of inter-set rest duration might be to influence one's ability to sustain performance within a single session. Additionally, two studies investigated effects of varying inter-set rest durations on training adaptations of youth soccer players (~10-15 years old) during 6 and 7 week-long interventions (Ramírez-Campillo et al., 2014, 2019). These studies reported no differences between 30-, 60-, and 120-seconds of inter-set rest in boys aged around 10-11 years. However, older (~15 years) participants achieved better training outcomes with inter-set rest of 120- compared to 30-seconds (Ramírez-Campillo et al., 2019). A training study including a cohort of an active adults for which the positive acute effects of manipulating inter-set rest duration were previously demonstrated (Kramer et al., 2019) is missing thus far.

Set structure manipulation can be used to reduce acute fatigue during lower body plyometric exercise (Hespanhol et al., 2007; Moreno et al., 2014). For example, vertical jump height decreased significantly starting from the 6th repetition during 2 sets of 10 continuous CMJs with 90 seconds inter-set rest in trained men (Moreno et al., 2014). However, no significant performance decrease was seen when the total volume and rest duration got redistributed into 5 and 2 jumps per set with 30- and 10-seconds of inter-set rest, respectively (Moreno et al., 2014). Similarly, 4 sets of 15 seconds continuous CMJs resulted in significantly more jumps and higher mean jump height compared to a single 60-second set in male volleyball players (Hespanhol et al., 2007). In practice, these two studies indicate that changing the set structure either by rest redistribution or splitting the total volume into smaller sets, seems like a beneficial strategy to reduce acute fatigue. However, this had not yet been shown beneficial during a plyometric training intervention. Only one study included in this review attempted to compare effects of traditional (5 sets of 20 repetitions) and cluster set (5 sets of 2 × 10 repetitions) structures during 6 weeks of plyometric training in active adults (Asadi & Ramírez-Campillo, 2016). The training program included repeated DJs performed twice per week with constant training volume and intensity throughout the study. The total rest time was equated between traditional (120 seconds between sets) and cluster set groups (90 seconds between sets and 30 seconds between clusters). Both groups significantly improved CMJ and standing long jump performance with no significant inter-group difference. Although it is possible that the rate of improvement was greater for one of the groups, this cannot be determined as this study included only pre- and post-intervention testing. Additionally, as mentioned above, as little as 6 continuous CMJs can cause a significant decrease of jumping performance in trained men (Moreno et al., 2014), which is supported by other studies showing significant decrease of jump height and increase of ground contact time occurring between 5th and 8th jump in male volleyball and basketball players performing continuous maximum effort CMJs (Dal Pupo et al., 2013) and jump height decreasing by 13.5% within first 10 CMJs performed by male volleyball players at a rate of 33 jumps per minute (Paulus et al., 2021). Therefore, future research should consider including cluster sets containing smaller number of repetitions as well as performing more frequent testing to detect rate of adaptation.

3.8 Fatigue compensation

Although neuromuscular fatigue is bound to ensue at some point during repeated jumping, athletes might be able to compensate for the initial onset of fatigue to sustain maximal jump height. In one study, vertical jump height decreased after 200 drop jumps, but time to peak power, eccentric- and concentric-phase duration, mean force, rate of force development, and eccentric peak power showed significant changes after only 50 repetitions without any significant decrease of jump height (Satkunskiene et al., 2021). This indicates that changes of jump technique might occur as a result of increasing fatigue way before it is no longer possible to sustain the maximal jump height. Strength and conditioning coaches should consider this when planning and monitoring plyometric training of their athletes. Also, it might be beneficial for researchers to include additional kinetic and kinematic parameters beside jump height when studying interaction between jumping tasks and fatigue.

3.9 Post-exercise recovery

The speed of recovery following the plyometric exercise is important for planning consecutive training sessions. Eleven studies investigated the recovery speed of knee extension MVIC for 24 hours or more post plyometric intervention (Chatzinikolaou et al., 2010; Kamandulis et al., 2016; Marginson et al., 2005; Miyama & Nosaka, 2004a, 2004b, 2007; Satkunskiene et al., 2021; Skurvydas et al., 2000, 2006, 2011, 2018). Only five of these studies however, included long enough follow-up duration to see the strength performance recovered to pre-intervention values (Marginson et al., 2005; Miyama & Nosaka, 2004a, 2007; Skurvydas et al., 2011, 2018). Out of the five studies, only one compared speed of recovery between two age groups, where (Marginson et al., 2005)pre-pubescent children recovered within 48 hours after 8 sets of 10 continuous CMJs with 1 minute of inter-set rest; however, performance of adult men was still significantly decreased 72 hours after the intervention (Marginson et al., 2005). The rest of the studies included only untrained or physically active adults whose knee extension MVIC performance recovered within 1 day (Miyama & Nosaka, 2007; Skurvydas et al., 2018), 4 days (Miyama & Nosaka, 2004a), and 14 days (Skurvydas et al., 2011) after fatiguing plyometric exercise. However, 1 day of rest was sufficient for recovery of MVIC force after 10 DJs from 60 cm, but 3 days were insufficient for full recovery following 5 sets of the same exercise (Miyama & Nosaka, 2007). This highlights the large effect that training volume has on the amount of time needed for recovery. Furthermore, not only does the training volume affect recovery time, but the training surface does as well. For example, 4 days were enough to see full recovery following 5 sets of 20 DJs from 60 cm performed on sand, but not when performed on a wooden surface (Miyama & Nosaka, 2004a). Unusually great differences in recovery time had between reported by two studies exploring effects of identical interventions (50 DJs from 50 cm with countermovement to 90 degrees of knee angle with 30 seconds of inter-repetition rest) on samples of similar training status, age, gender, height, and weight (Skurvydas et al., 2011, 2018). One of these studies reported full recovery of knee extension MVIC as soon as 24 hours after the intervention (Skurvydas et al., 2018), while the other reported MVIC to be significantly decreased 7 days after the intervention and fully recovered on day 14 (Skurvydas et al., 2011). This discrepancy could be caused by a confounder variable such as differences in daily activities between the two groups or different follow-up measurement time points. One study measured knee extension immediately and 1 day after the intervention (Skurvydas et al., 2018), while the other one measured MVIC performance at 2 minutes, 3 days, 7 days, and 14 days after the intervention (Skurvydas et al., 2011). However, to explain observed discrepancies, there would need to be an initial recovery to baseline values followed by the secondary significant decrease of performance between 1 and 3 days after the intervention. Although, we do not know if that could have been the case based on the results.

Muscle soreness of knee extensors was evaluated by eleven studies (Chatzinikolaou et al., 2010; Fernandes et al., 2020; Kamandulis et al., 2016; Kons et al., 2020; Miyama & Nosaka, 2004a, 2004b, 2007; Satkunskiene et al., 2021; Skurvydas et al., 2006, 2018; Skurvydas, Kamandulis, & Masiulis, 2010) and five studies evaluated lower extremities as a whole (Dias et al., 2022; Eiras et al., 2009; Kamandulis et al., 2019; Marginson et al., 2005; Skurvydas et al., 2002). All 16 studies reported significantly increased muscle soreness at some point during the follow-up period after a plyometric intervention. This could be related to the novelty of a plyometric stimulus as all included participants were either untrained or unaccustomed to systematic plyometric training. Nine studies included follow up period equal to or longer than 72 hours during which muscle soreness was assessed at least on 3 occasions (Chatzinikolaou et al., 2010; Dias et al., 2022; Eiras et al., 2009; Kamandulis et al., 2019; Marginson et al., 2005; Miyama & Nosaka, 2004a, 2007; Skurvydas et al., 2006, 2011). These studies reported peak muscle soreness between 24 and 48 hours after intervention. Five studies reported full recovery within the follow-up period which occurred at 48- (Marginson et al., 2005; Miyama & Nosaka, 2007), 72- (Dias et al., 2022), 96- (Chatzinikolaou et al., 2010), and 168-hours (Kamandulis et al., 2019) post-intervention. The differences in the recovery durations might be to a certain extent explained by differences in participant characteristics and intervention parameters. For example, muscle soreness fully recovered 48 hours after 8 sets of 10 consecutive CMJs with 1 minute of inter-set rest but only in pre-pubescent boys but not in adults (Marginson et al., 2005). As mentioned above, pre-pubescent age group tends to be more resistant to fatigue from plyometric exercise compared to adults. Untrained adults in another study also needed 48 hours to recover following 10 DJs from 60 cm but the muscle soreness was only reduced by ~50% in 72 hours when performing 5 sets of this protocol with 1 minute of inter set rest (Miyama & Nosaka, 2007). On the other hand, different study reported full recovery of adult men 72 hours after 5 sets of 20 DJs from 50 cm with 2 minutes of inter-set rest, but their training status was probably higher as inclusion required performing at least 3-4 weekly resistance and aerobic training sessions for 6 months preceding the intervention (Dias et al., 2022). Similarly, strength and endurance trained men reached full recovery 96 hours after 5 sets of 10 hurdle and 10 drop jumps from 50 cm (Chatzinikolaou et al., 2010). Lastly, muscle soreness level returned to baseline on 7th day after 100 DJs from 40 cm with 20 seconds of inter-repetition rest in untrained women, but there were no data collected between 3rd and 7th day of follow-up (Kamandulis et al., 2019). Therefore, the exact point of recovery is not possible to identify. Overall, the level of muscle soreness following a fatiguing lower body plyometric exercise seems to be largely influenced by the biological age and training status of an individual, peaking around 24 to 48 hours post-exercise, and depending on the volume of work performed diminishing between 1 to 4 days post-exercise.

Creatine kinase activity, which is often used as a marker of muscle damage (Brancaccio et al., 2007), was reported to be significantly elevated at some point between 24- and 72-hours after a plyometric intervention by all included studies which measured this parameter

(Chatzinikolaou et al., 2010; Dias et al., 2022; Eiras et al., 2009; Fernandes et al., 2020; Kamandulis et al., 2016; Miyama & Nosaka, 2004a, 2004b, 2007; Satkunskiene et al., 2021; Skurvydas et al., 2006, 2011, 2018; Skurvydas, Kamandulis, & Masiulis, 2010; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010). Seven studies included at least 3 follow-up measurements covering at least 48 hours after the intervention (Chatzinikolaou et al., 2010; Dias et al., 2022; Eiras et al., 2009; Fernandes et al., 2020; Miyama & Nosaka, 2004a, 2004b, 2007). Peak concentrations were reported at 24- (Eiras et al., 2009; Fernandes et al., 2020; Miyama & Nosaka, 2004a, 2004b, 2007) and 48-hours after the intervention (Chatzinikolaou et al., 2010; Dias et al., 2022). There is a possible influence of training status as studies reporting peak concentration at 48 hours after the intervention included trained participants in contrast to the other four studies which characterized their participants as untrained. Additionally, studies reporting sooner creatine kinase peak included lower total volume (Eiras et al., 2009; Miyama & Nosaka, 2007), lower intensity (Eiras et al., 2009; Fernandes et al., 2020), and longer inter-repetition rest (Miyama & Nosaka, 2004a, 2004b) which could also play a role. The return to baseline levels was reported at 48- (Fernandes et al., 2020; Miyama & Nosaka, 2007), 72- (Miyama & Nosaka, 2004a), and 98-hours (Chatzinikolaou et al., 2010) post-intervention. Possible factors influencing the quicker recovery could be the lower exercise volume (Miyama & Nosaka, 2007) and intensity (Fernandes et al., 2020). We would expect to see quicker recovery in the study reporting full recovery after 98 hours as the intervention included a less demanding work-to-rest ratio and the training status of the participants was higher compared to the other three studies. On the other hand, this study reported the lowest baseline and peak concentrations, rate of increase, and inter-individual variation out of the four studies (Chatzinikolaou et al., 2010). As such, we hypothesize that these results might be influenced by an interplay between training status, training specificity, measurement methods used, and possibly other genetic (George et al., 2016) or lifestyle related factors.

Blood lactate concertation, often used in exercise as an indicator of disrupted physiological equilibrium (Goodwin et al., 2007), was measured by 8 studies out of which all reported significantly elevated levels after a plyometric intervention (Brown et al., 2010; Ducrocq et al., 2020; Kramer et al., 2019; Miyama & Nosaka, 2007; Pereira et al., 2008; Skurvydas, Kamandulis, & Masiulis, 2010; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010; Wadden et al., 2012). It seems that decreasing inter-repetition rest duration during plyometric exercise results in significant increases of blood lactate concentration (Ducrocq et al., 2020; Kramer et al., 2019; Pereira et al., 2008); however, the same effect was not shown for inter-set rest (Kramer et al., 2019). Four studies measured the blood lactate concentration during the recovery after the exercise, but neither of them used long enough follow-up period (10 to 60 minutes) to see the full recovery to baseline levels (Brown et al., 2010; Skurvydas, Kamandulis, & Masiulis, 2010; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010; Wadden et al., 2012).

3.10 Repeated bout effect

When studying the effect of fatiguing plyometric exercise, the researchers must select a group of participants and introduce them to their intervention. Some interventions are very similar to what the participants face in their regular training, others greatly differ from the usual training stimulus. Additionally, every plyometric intervention, even those that are routinely used in training practice, would be novel for untrained participants and probably also for trained participants if plyometrics were not part of their training routine. Therefore, we must stay cautious when interpreting the results of studies that observe the effects of a single plyometric session as multiple repetitions of such stimulus will likely lead to different outcomes. This effect, known as repeated bout effect, had been explored in six of the included studies (Dias et al., 2022; Kamandulis et al., 2016; Miyama & Nosaka, 2004b, 2007; Paulus et al., 2021; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010). Five sets of 20 DJs from 50 cm with countermovement to 90 degrees of knee flexion led to significant decrease of jump height, increased muscle soreness, and increased creatine kinase concentration in trained men unaccustomed to plyometric exercise (Dias et al., 2022). However, the same stimulus repeated after 14 days of rest did not cause any significant changes of these parameters compared to baseline. Another study reported similar response to 5 sets of 10 DJs from 60 cm in untrained men repeated twice with 14 days of rest (Miyama & Nosaka, 2007). The authors also included the second group which performed only one set of 10 DJs during the first session followed by 5 sets after 14 days. Interestingly, the results showed similar reduction of negative effects of the second plyometric session in both groups. Another three of the mentioned studies also observed significant positive effects after repeated fatiguing plyometric protocols with 3- (Skurvydas, Kamandulis, Stanislovaitis, et al., 2010), 8- (Miyama & Nosaka, 2004b), and 28-days (Kamandulis et al., 2019) of inter-day rest. The observed benefits included reduced muscle soreness(Kamandulis et al., 2019; Miyama & Nosaka, 2004b), faster recovery of knee extension torque (Kamandulis et al., 2019; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010), faster recovery of vertical jump performance (Miyama & Nosaka, 2004b), and reduced increase of creatine kinase concentration (Miyama & Nosaka, 2004b; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010). However, one study reported that competitive male volleyball players experienced similar rates of decreasing jump height during 50 CMJs with a jump frequency of 33 jumps per minute, performed on two occasions separated by 7 days (Paulus et al., 2021). Based on these results, coaches should expect to see faster recovery when novel plyometric exercise is repeated by untrained or inexperienced individuals but not necessarily in individuals already habituated to systematic plyometric training.

3.11 Between session considerations

Training frequency and inter-day rest could also be very important for management of cumulative fatigue resulting from plyometric training. Five of the included studies investigated impact of training frequency on plyometric training outcomes (Bianchi et al., 2018; Bouguezzi et al., 2020; Ramírez-Campillo et al., 2018; Saez de Villarreal Saez et al., 2008; Yanci et al., 2017) out of which, three (Bianchi et al., 2018; Bouguezzi et al., 2020; Ramírez-Campillo et al., 2018) reported significant improvements of explosive strength, linear speed, agility, and endurance after short-term plyometric training, but with no significant differences between 1 and 2 training sessions per week in pre-pubescent (~12 years) male soccer players (Bouguezzi et al., 2020), elite youth (~17 years) male soccer players (Bianchi et al., 2018), and regional-level adult (~21 years) female soccer players (Ramírez-Campillo et al., 2018). That is both with (Bouguezzi et al., 2020; Ramírez-Campillo et al., 2018) and without (Bianchi et al., 2018) equated weekly training volume. On the other hand, plyometric training program without equated training volume performed twice per week was more effective than a single weekly session and equally as effective as 4 weekly sessions in improving vertical jump and maximal strength of lower extremities in physically active male college students (Saez de Villarreal Saez et al., 2008). Furthermore, 6 weeks of volume equated plyometric training resulted in no change of jump height in competitive adult male futsal players performing one training session per week, but two weekly sessions led to significantly decreased performance (Yanci et al., 2017). However, this might be partially explained by the interference effect resulting from concurrent high-volume technical and tactical training in combination with extensive plyometric training experience of the included participants.

Inter-day rest duration was investigated by two of included studies. (Asadi, 2015; Ramírez-Campillo et al., 2015). One reported no differences in performance improvements between the 24- and 48-hours of inter-day rest in youth soccer players (~14 years) after 6 weeks of plyometric training performed 2 times per week (Ramírez-Campillo et al., 2015). On the other hand, a training intervention of the same duration and training frequency led to significantly improved sprinting and agility performance when using 72- compared to 48-hours of inter-day rest in active collegiate students (Asadi, 2015). Post-exercise fatigue could be possible explanation of these results as similar interventions shown to cause acute fatigue lasting a few days after plyometric session (Dias et al., 2022; Miyama & Nosaka, 2004a, 2004b). Therefore, the interventions were challenging enough to expect benefits of extended rest. On the other hand, the post-exercise fatigue could to some extent mitigate negative effects of inter-day fatigue, but relatively short duration of these plyometric programs (6 weeks) might not be enough to allow the performance changes to emerge. Furthermore, the link between age, training status, and fatigue resulting from plyometric exercise could also play a role in presented results. However, it is not yet possible to recommend any specific training frequency or inter-day rest based on the current body of research.

3.12 Conclusions

Based on the available literature, it seems that required rest duration is dependent on the age and training status of the athlete. For example, untrained and unexperienced individuals require longer rest periods than trained individuals, except for children, who are presumably untrained in terms of structured training. However, children may be exposed to greater plyometric volumes as part of their habitual activity and (un)structured play, which may also be a point to consider in practice and in future research. Opposed to age and training status, gender does not seem to significantly influence the fatigue resulting from single plyometric session. Furthermore, manipulating inter-repetition rest, inter-set rest, and set structure seem promising in reducing the effects of fatigue from physically demanding plyometric sessions. Although, the benefits will likely be highly specific to different contexts. On the other hand, programing unnecessary long rest durations to avoid fatigue might result in significantly increased training duration which could be spent more productively. Novel or excessively demanding plyometric sessions have been shown to significantly reduce knee extension MVIC and increase muscle soreness, creatine kinase activity, and blood lactate concentration, with full recovery usually occurring within 7 days after the exercise. The recovery time seems to greatly depend on interaction between athlete characteristics and parameters of performed plyometric session (e.g., training volume, training intensity, specific exercises). However, the repeated bout effect and therefore decreased recovery time has been shown after repeated exposures to plyometric stimuli. A few studies investigated effects of training frequency and inter-day rest on short term plyometric training outcomes. However, no conclusive recommendations could be provided yet. Further research in this area would be desirable to help answer many arising questions and provide guidance for effective application of within and between session rest periods in plyometric training. It is true that the work done so far could provide a solid foundation for further research of these topics, but some frequent limitations should be addressed. For example, the high prevalence of untrained participants in acute studies limits the application of the findings to populations usually involved in plyometric training. Additionally, arm swing is frequently limited in research which is not usual in plyometric training without added resistance, as restricting the arms would greatly reduce training specificity. Furthermore, studies often include short follow-up periods which may not allow full recovery to be observed after the intervention. Finally, many studies could not be included in this review because the rest period length was not specified. Therefore, rest period duration should become standard parameter included in the methods sections of future plyometric studies.

4 Factors affecting rest-duration requirements: An update to the original systematic literature review

Since research on rest periods in plyometric training is continually evolving, we performed an updated systematic literature search on January 2nd, 2024, to identify the most current information in this field. This search largely mirrored the original search (refer to the initial parts of the previous chapter for methodological details), differing only in applied publication year restriction which was set to include studies published from 2021 onwards.

4.1 Search results

The literature search across four databases identified a total of 3,113 studies. After removing duplicates and screening for eligibility, seven studies met our inclusion criteria. Backward citation searching of the eligible studies did not yield any additional eligible studies. Figure 2 provides a flow chart of the literature search process.

4.2 Characteristics of included studies

A total of 191 participants (187 males and 4 females) were involved in the included studies. One study included participants of both sexes (Ridard et al., 2022), while the rest included only male participants. One study included only youth participants (Hernandez-Martinez et al., 2023), and the remaining studies included only adult participants. Five studies classified the training status of participants as physically or recreationally active (Dal Pupo et al., 2021; Kamandulis et al., 2022; Knihs et al., 2022; Moghadam et al., 2023; Ridard et al., 2022) and two as competitive and/or trained (Hernandez-Martinez et al., 2023; Wannop et al., 2023). Three studies used a within-subject design (Dal Pupo et al., 2021; Hernandez-Martinez et al., 2023; Moghadam et al., 2023), three used a between-subjects design (Knihs et al., 2022; Ridard et al., 2022; Wannop et al., 2023), and one study reported two experiments using both within- and between-subject design (Kamandulis et al., 2022). Tables 6 and 7 provide overviews of participant characteristics and summary of experimental protocols and outcomes, respectively.

Figure 2. Flow chart of the literature search process.

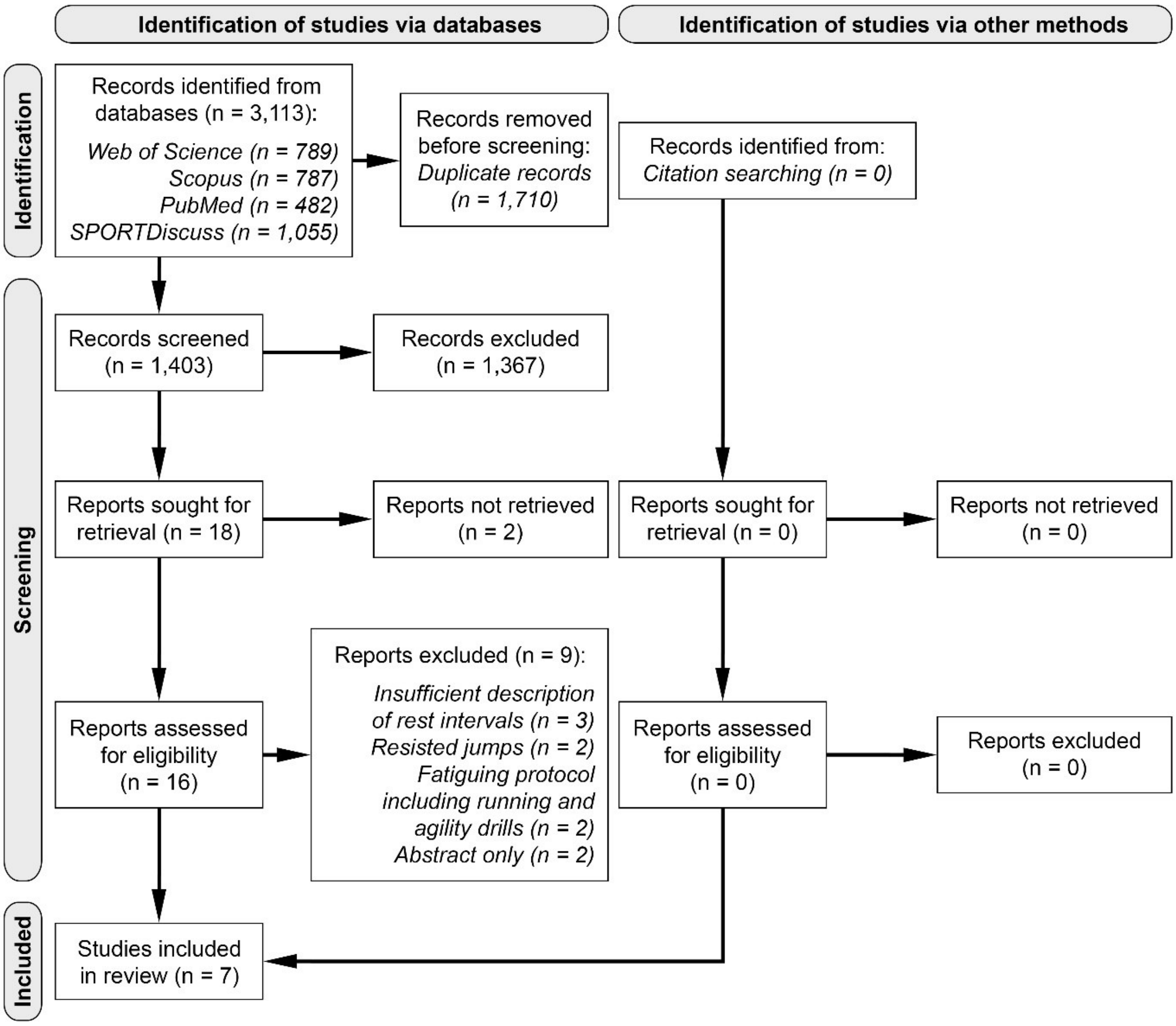


Table 6. Characteristics of individual study samples.

Study	Sample size	Sex (n)	Age [years]	Height [cm]	Mass [kg]	Training status
Dal Pupo et al., 2021	EG1: 12 EG2: 10	M M	25.7 ± 5.5 27.0 ± 6.0	180.0 ± 7.1 179.2 ± 0.4	76.03 ± 10.15 73.60 ± 7.63	Physically active
Hernandez-Martinez et al., 2023	EG1: 15 EG2: 14 CG: 13	M M M	14.7 ± 0.26*	166.0 ± 3.7*	58.1 ± 1.47*	Competitive volleyball players without systematic plyometric training experience
Kamandulis et al., 2022	EG: 12	M	23.2 ± 3.1	NS	83.2 ± 4.5	Recreationally active
	EG1: 8 EG2: 8	M M	30.9 ± 8.5 30.0 ± 6.0	NS	85.5 ± 9.3 86.0 ± 12.7	Recreationally active

*1RM = one repetition maximum, BW = bodyweight, CG = control group, EG = experimental group, F = female, M = male, NS = not specified, PT = plyometric training, * combined across all groups, # only range reported.*

Table 6. Continued.

Study	**Sample size**	**Sex (n)**	**Age [years]**	**Height [cm]**	**Mass [kg]**	**Training status**
Knihs et al., 2021	EG: 17	M	26.8 ± 3.3	181.2 ± 6.4	79.3 ± 11.5	Physically active
Moghadam et al, 2023	EG1: 12 EG2: 11 EG3: 13 EG4: 11	M M M M	26.5 ± 3.9*	173.7 ± 7.0*	78.0 ± 9.2*	Recreationally active men without previous systematic plyometric training experience
Ridard et al., 2022	EG: 15	M (11) F (4)	26 ± 5*	174 ± 9*	70 ± 10*	Physically active
Wannop et al., 2023	EG: 20	M	≥ 18	191 ± 12	88.1 ± 9.2	Varsity basketball and volleyball players

Table 7. Experimental interventions and outcomes of the included studies.

Study	Experimental protocol	Outcome assessment
Dal Pupo et al., 2021	EG1: 6 × 30 s of continuous CMJs, EG2: 6 × 30 s of treadmill running at 50 % anaerobic speed reserve (maximal aerobic speed + ((maximal sprinting speed – maximal aerobic reserve)/ 2)); 1:6 work-to-rest ratio	Isokinetic knee extension and flexion of dominant (kicking) side at 180°.s^{-1}, rating of perceived exertion, muscle soreness (anterior/posterior thigh, anterior/posterior shank)
Hernandez-Martinez et al., 2023	8 weeks training intervention; CG: traditional volleyball training, EG1: PT session replacing part of volleyball training once per week, EG2: same as EG1 but twice per week (non-equated weekly PT volume)	CMJ, CMJ with arm swing, squat jump, DJ, 5 m and 10 m sprint, service speed, and rating of perceived exertion
Kamandulis et al., 2022	50 DJs from 50 cm with countermovement to 90° knee angle, 20 s and 5 min IRR in randomized order performed 3 months apart	MVIC and electrically induced (20 and 100 Hz) knee extension (110° knee angle), muscle soreness, and plasma creatine kinase activity
	EG1: 50 DJs from 50 cm with countermovement to 90° knee angle and 20 s IRR, EG2: same as EG1 but with 5 min IRR	Muscle biopsy from vastus lateralis for quantitative polymerase chain reaction (qPCR) analysis
Knihs et al., 2021	7 × 10 continuous CMJs and 14 × 10 continuous CMJs performed in this order 7 days apart	CMJ (jump height, power output, net impulse, and vertical stiffness),

CG = control group, CMJ = countermovement jump, DJ = drop jump, EG = experimental group, IRR = inter-repetition rest, ISR = inter-set rest, IDR = inter-day rest, MVIC = maximal voluntary isometric contraction, PT = plyometric training.

Table 7. Continued.

Study	Experimental protocol	Outcome assessment
Moghadam et al, 2023	6 weeks of PT with 2 weekly sessions including 2 lower- and 2 upper-body exercises; 3-5 sets of EG1: 10-12 repetitions with 90 s ISR, EG2-4: 2×5-6 repetitions with 10, 20, and 30 s rest between clusters and 80, 70, and 60 s ISR, respectively	Back squat 1RM, chest press 1RM, hand grip, standing long jump, 20 m sprint, 4 × 9 m shuttle run test, 60 % 1RM back squat and chest press to failure, perceived fatigue
Ridard et al., 2022	100 DJs from 45 cm with countermovement to 90° knee angle and 15 s IRR; followed by sets to 20 DJs until electrically evoked knee extension plateaued	MVIC and electrically induced (20 and 120 Hz) knee extension (90° knee angle)
Wannop et al., 2023	CMJs to failure (3 consecutive jumps below 88% of maximal jump height or refusing to continue), 20 s IRR	Ground reaction forces, 3D kinematics of lower extremity

4.3 Risk of bias assessment

The risk of bias was assessed using the same method as the original review. Four studies were assessed using RoB 2.0 tool for randomized trials (Dal Pupo et al., 2021; Hernandez-Martinez et al., 2023; Kamandulis et al., 2022; Moghadam et al., 2023), one using RoB 2.0 tool for crossover trials (Kamandulis et al., 2022), and three using ROBINS-I tool (Knihs et al., 2022; Ridard et al., 2022; Wannop et al., 2023). However, one of the included studies (Kamandulis et al., 2022) reported results of two separate experiments from which one was assessed using RoB 2.0 tool for randomized trials and another one using RoB 2.0 tool for crossover trials. Out study was assessed for bias due to randomization process, only one was judged as low risk (Kamandulis et al., 2022), while three included some concerns due to missing details about the randomization method and about concealing the allocation sequence (Hernandez-Martinez et al., 2023; Kamandulis et al., 2022; Moghadam et al., 2023). One study was judged as high risk due to concerning between-group differences at baseline (Dal Pupo et al., 2021). The single crossover study included was judged low risk for bias due to period and carryover effects (Kamandulis et al., 2022). Two studies were considered high risk for bias due to deviations from intended interventions (Dal Pupo et al., 2021; Moghadam et al., 2023) with concerns regarding control of important non-protocol interventions in both cases. Concerns about possible missing outcome data were present in six studies due to inability to confirm data availability for all or nearly all participants (Dal Pupo et al., 2021; Hernandez-Martinez et al., 2023; Kamandulis et al., 2022; Knihs et al., 2022; Moghadam et al., 2023; Wannop et al., 2023). High risk of bias due to concerns regarding outcome measurement was present in one study (Moghadam et al., 2023) because a measurement instrument with poor reliability which is unlikely to be sensitive to plausible intervention effects – handheld stopwatch – was used to measure linear and change of direction speed performance. All included studies had some concerns regarding the selection of reported results, as analysis according to prespecified plans could not be confirmed. Three domains were assessed only for non-randomized studies: confounding, selection of participants, and classification of interventions, and all were judged to be of low risk. The full risk of bias assessment reports are presented in Tables 8 and 9.

Table 8. Risk of bias assessments of randomized designs.

Study	D1	DS	D2a	D2b	D3	D4	D5
Dal Pupo et al. 2021 [a]	×	NA	−	×	−	+	−
Hernandez-Martinez et al. 2023 [a]	−	NA	−	+	−	+	−
Kamandulis et al. 2022 (experiment I) [b]	−	+	−	+	−	+	−
Kamandulis et al. 2022 (experiment II) [a]	+	NA	−	+	−	+	−
Moghadam et al. 2023 [a]	−	NA	−	×	−	×	−

D1 = Randomization process, DS = Period and carryover effects, D2a = Deviations from intended intervention: effect of assignment to intervention, D2b = Deviations from intended intervention: effect of adhering to intervention, D3 = Missing outcome data, D4 = Measurement of the outcome, D5 = Selection of the reported result, × = High risk of bias, − = Some concerns, + = Low risk of bias, NA = Not applicable, a = RoB 2.0 for randomized trials, b = RoB 2.0 for crossover trials, c = RoB 2.0 for cluster-randomized trials.

Table 9. Risk of bias assessment of non-randomized designs.

Study	D1	D2	D3	D4	D5	D6	D7
Knihs et al., 2021	+	+	+	+	?	+	?
Ridard et al., 2022	+	+	+	+	+	+	?
Wannop et al., 2023	+	+	+	+	?	+	?

D1 = Confounding, D2 = Selection of participants, D3 = Classification of interventions, D4 = Deviations from intended intervention, D5 = Missing data, D6 = Measurement of outcomes, D7 = Selection of the reported result, ! = Critical risk of bias, × = Serious risk of bias, − = Moderate risk of bias, + = Low risk of bias, ? = No information.

4.4 Synthesis and discussion of the outcomes

The studies included in this update do not meaningfully expand our understanding of the relationship between athlete characteristics, rest intervals, and fatigability in lower body plyometrics due to high homogeneity in age, gender, and training status of the research samples. All except one study included exclusively male participants, and the single mixed gender study did not explore effects of gender (Ridard et al., 2022).

Delayed onset muscle soreness has been shown to occur approximately 24 hours following fatiguing plyometric exercise in untrained or unaccustomed individuals (Kamandulis et al., 2019; Skurvydas et al., 2002). Two recent studies examined delayed onset muscle soreness and decreased leg strength following fatiguing plyometric activity (Dal Pupo et al., 2021; Kamandulis et al., 2022). A high intensity interval protocol including 6 sets of 30-second continuous CMJs with a 1:6 work-to-rest ratio resulted in significant muscle soreness in quadricep, hamstring, and calf muscles, lasting until the end of the follow-up period 48 hours post-intervention (Dal Pupo et al., 2021). The same study reported a significant decrease in concentric and eccentric torque in knee extensors and flexors for the entire 48-hour follow-up period. These negative effects were more severe compared to an identical running protocol, possibly due to greater muscle damage from higher vertical ground reaction forces associated with jumping. These results align with previous studies showing similar muscle soreness and significant decreases in isometric knee extensor strength 48 hours after 2 sets of 50 continuous CMJs (Skurvydas, Kamandulis, & Masiulis, 2010), and with outcomes indicating that interval DJ exercise produces similar cardio-ventilatory stimulus but greater peripheral fatigue and quadriceps activation compared to interval running (Ducrocq et al., 2020).

Another study investigated mechanisms responsible for delayed onset muscle soreness by requiring participants to perform 50 DJs with a countermovement to a 90-degree knee angle with either 20 seconds or 5 minutes of inter-repetition rest (Kamandulis et al., 2022). Five minutes of inter-repetition rest, represents much longer rest duration compared to similar studies (Kamandulis et al., 2019; Satkunskiene et al., 2021; Skurvydas et al., 2011, 2018), this was expected to allow restoration of intrinsic spatial structures and function of non-contractile muscle proteins. The study reported significantly increased muscle soreness peaking at 24-48 hours post-intervention for both rest intervals, with lower muscle soreness following the longer rest duration. Furthermore, similar decreases in voluntary and high-frequency (100 Hz) electrically stimulated isometric knee extension torque were observed after both protocols, but shorter rest duration led to more severe and longer-lasting decreases in low-frequency (20 Hz) torque. This suggests that mechanical damage to skeletal muscle extracellular matrix components plays an important role in development and recovery of delayed onset muscle soreness (Kamandulis et al., 2022).

A similar methodological approach was used in another study where participants performed 100 DJs from 45 cm with a countermovement to a 90-degree knee angle and 15 seconds of inter-repetition rest, followed by additional sets of 20 DJs until electrically stimulated isometric knee extension plateaued (Ridard et al., 2022). Significant low-frequency fatigue and decreased maximal isometric strength of knee extensors were reported, with no associated central drive impairment. These results support previous findings (Kamandulis et al., 2019; Skurvydas et al., 2018), demonstrating the feasibility of field testing in a more sport-specific environment.

Two studies investigated acute performance changes in response to fatiguing lower body plyometric protocols (Knihs et al., 2022; Wannop et al., 2023). One reported peak and mean power output to be reliable and sensitive metrics for detecting small performance changes and monitoring acute fatigue, while jump height was less sensitive (Knihs et al., 2022). The other study analyzed fatigue-related changes in ankle, knee, and hip joint biomechanics during repeated maximal effort jumps to failure, showing significant reductions in hip and ankle joint power and energy, mitigated by increased knee joint power (Wannop et al., 2023). These findings support the concept of fatigue compensation from the original literature review, where subtle adjustments in jumping technique sustain performance despite early onset of fatigue. Therefore, making jump height less sensitive compared to power output and other jump related performance variables.

Two short-term plyometric training interventions were also included (Hernandez-Martinez et al., 2023; Moghadam et al., 2023). One study compared three different cluster set configurations (10-, 20-, and 30-second of inter-cluster rest) with traditional set configuration over six weeks, finding significant increases in various anthropometric and performance metrics in all conditions, with only differences in rating of perceived exertion favoring 20- and 30-second cluster sets over 10-second cluster and traditional sets (Moghadam et al., 2023). These outcomes resemble non-significant differences in outcomes following 6 weeks of cluster and traditional set training from the original literature review (Asadi & Ramírez-Campillo, 2016). The other study compared plyometric training frequencies with equated training volumes in volleyball players, finding no differences between one and two weekly sessions, both outperforming traditional technical volleyball training (Hernandez-Martinez et al., 2023). These outcomes confirm previous findings regarding short-term training frequencies (Bouguezzi et al., 2020; Ramírez-Campillo et al., 2018).

In conclusion, this literature review update does not provide any definitive answers regarding optimal applications of rest periods in lower body plyometric training. However, it confirms previous findings and expands on existing concepts, offering important insights for future research. The continuous interest in this topic suggests the relevance of the practical part of this dissertation thesis, which aims to contribute valuable information to this field.

EXPERIMENTAL PART

5 Primary and secondary hypotheses

Based on the systematic review of available literature the primary hypothesis had been formed, stating that shorter inter-repetition rest would result in significantly greater performance detriments with earlier onset during a set of maximal effort repeated CMJs compared to conditions with longer inter-repetition rest durations. Furthermore, shorter inter-repetition rest would likely result in greater physiological response, larger subjective exertion, and slower post-exercise recovery than longer inter-repetition rest.

Additionally, three secondary hypotheses were formed.

Firstly, it was hypothesized that BJ will result in significantly less impact force than HJ and CMJ, and that BJ and HJ would result in significantly greater countermovement depth in an effort to maximize the propulsion time in response to the need of overcoming an obstacle which would lead to greater ground reaction forces, concentric velocities, and concentric power compared to the CMJ.

Secondly, it was hypothesized that the jump variation with higher landing height (BJ) and consequently producing lower impact forces upon landing would result in no significant decrease of concentric performance (ground reaction forces, velocity, power, and jump height) across a set of repeated maximal effort jumps. On the other hand, it was hypothesized that decrease of concentric jumping performance will occur when using jump variation with higher impact forces (HJ).

Finally, we hypothesized that the anthropometric and performance characteristics of our experimental samples would be significantly correlated with their jumping performance and the decrease in jumping performance during a set of 50 continuous CMJs. Specifically, we anticipated that better performance in all three jump types measured in the first data collection would be associated with a lower levels of body fat percentage. Additionally, we expected to find a significant negative correlation with greater body weight and no significant relationships between the rest of the anthropometric parameters and the variables describing jumping performance. Furthermore, we predicted that individuals and subgroups with higher levels of maximal strength, a less steep back squat load-velocity profile, lower SJ, CMJ, and DJ performance, as well as higher jump performance potentiation resulting from countermovement, would demonstrate greater fatigue resistance, more efficient recovery, and lower subjective exertion during and after the set of continuous CMJs performed in the second data collection.

6 Methodology

A crossover repeated measures design was used in this thesis. Two distinct data collections were performed to gather the data necessary to answer research questions related to the aforementioned research problem.

6.1 Participants

The required sample sizes for both parts of data collection were calculated via a priori power analysis using G*Power 3.1 (RRID:SCR_013726; G-Power, Brunsbüttel, Germany). The results of the power analysis indicated 19 participants to be required for the first data collection (effect size = 0.80; α err. prob. = 0.05; Power (1–β err. prob.) = 0.90) and 12 participants for the second part of data collection (effect size = 1.20 (Kramer et al., 2019; Pereira, de Freitas, et al., 2009; Pereira et al., 2008; Pereira, Morse, et al., 2009); α err. prob. = 0.05; Power (1–β err. prob.) = 0.95). To fulfill these requirements and to account for a possible drop-out of participants during the data collection process, 21 and 16 healthy, recreationally trained, university-aged men were recruited to participate in the first and second part of the data collection, respectively. All participants had to meet the following inclusion criteria: a) valid certificate from sport physician clearing the individual for participating in sport related activities; b) previous experience with strength training and plyometric training; c) back squat 1RM greater than participant's own body weight (only the second data collection); d) pain free vertical jumps and squats with barbell; e) ability to perform squats to the depth in which participant's femur bone is parallel to the floor; f) no reported pain, acute injuries, or ongoing post-injury/post-surgery rehabilitation for at least 6-months prior to enrolling in this data collection; g) absence of infectious, asthmatic, cardiovascular, and musculoskeletal diseases. In total, three participants did not complete the data collection. One participant involved in the first data collection discontinued his participation due to personal reasons unrelated to the experiment. Furthermore, two participants were excluded from the second data collection due to not meeting the minimal required lower body strength and failing to complete all parts of the experiment after reaching premature volitional failure during one of the experimental protocols, respectively. Therefore, 20 and 14 participants were included in the final analysis of the first and second part of the data collection, respectively. All participants regularly participated in sports (soccer, basketball, handball, martial arts, track and field, cycling, and weightlifting) but did not compete in these sports professionally. Characteristics of included experimental samples are presented in Table 10. Figure 3 depicts back squat load-velocity profiles of individual participants included in the second data collection.

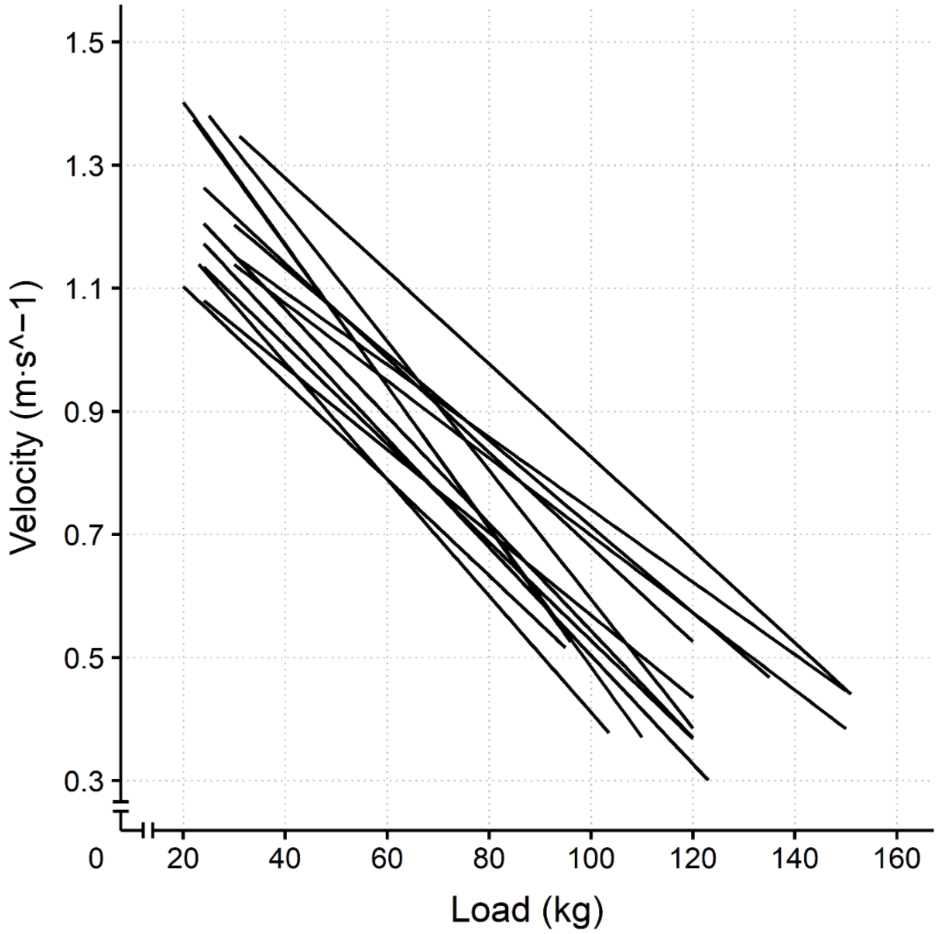
Table 10. Characteristics of experimental samples.

	First data collection	**Second data collection**
n	20	14
Age (years)	25.17 ± 3.48	25.50 ± 3.47
Body height (m)	1.80 ± 0.04	1.82 ± 0.08
Body mass (kg)	80.00 ± 7.82	85.15 ± 10.76
Body fat (%)	11.46 ± 2.72	10.48 ± 5.58
Squat jump height (m)	–	0.46 ± 0.04
Countermovement jump height (m)	0.41 ± 0.06	0.50 ± 0.04
Drop jump height (m)	–	0.49 ± 0.04
Reactive strength index	2.35 ± 0.60	–
Back squat LVP slope ($m \cdot s^{-1} \cdot kg^{-1}$)	–	-0.009 ± 0.002
Absolute back squat 1RM (kg)	–	132.18 ± 17.72
Relative back squat 1RM ($kg \cdot kg^{-1}$)	–	1.57 ± 0.22

1RM = one repetition maximum, LVP = load-velocity profile.

All participants received a detailed explanation of experimental procedures prior to participating in our experiments and provided written informed consent, which was approved by the university’s ethics committee (188/2021). Participants were asked to make no changes to their normal dietary and supplementation habits throughout the study, to refrain from strenuous lower-body exercise before the experimental sessions and during the rest days, to avoid sleep restriction before the experimental sessions (≥ 7 hours of sleep), and to refrain from consuming food and beverages at least 2 hours before each experimental session.

Figure 3. Back squat load-velocity profiles of individual participants from second data collection.

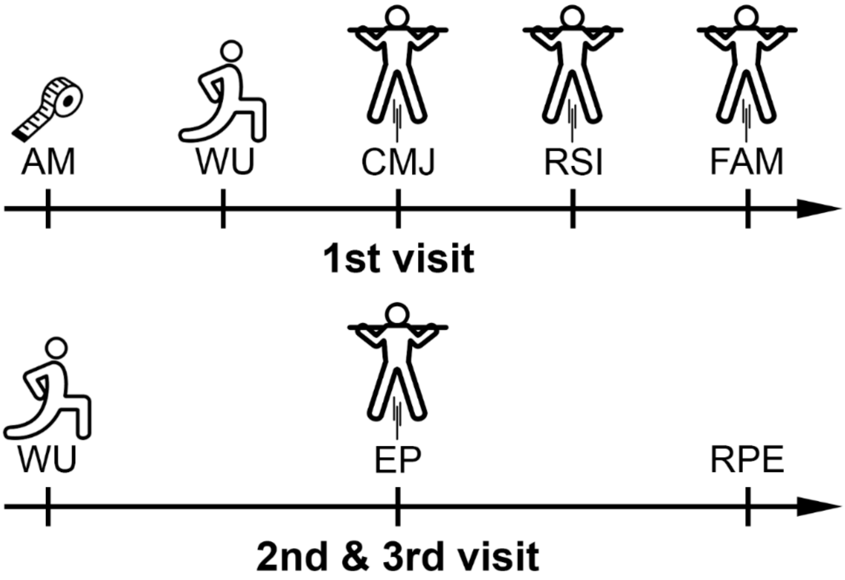


6.2 Data collection

6.2.1 First data collection

Each participant underwent three laboratory visits on non-consecutive days (≥ 48 h of rest) with constant time of the day (±1 h). The first visit included detailed explanation of experimental design followed by signing the informed consent, anthropometric measurements, standardized warm-up, CMJ test, reactive strength index (RSI) test, and familiarization with BJ, HJ, and rating of perceived exertion (RPE) scale. The second and third visits included standardized warm-up, 30 repetitions of either BJs onto a 50 cm box or HJs over a 50 cm hurdle in counterbalanced order, and RPE. The experimental protocol is depicted in Figure 4.

Figure 4. Experimental protocol – first data collection.

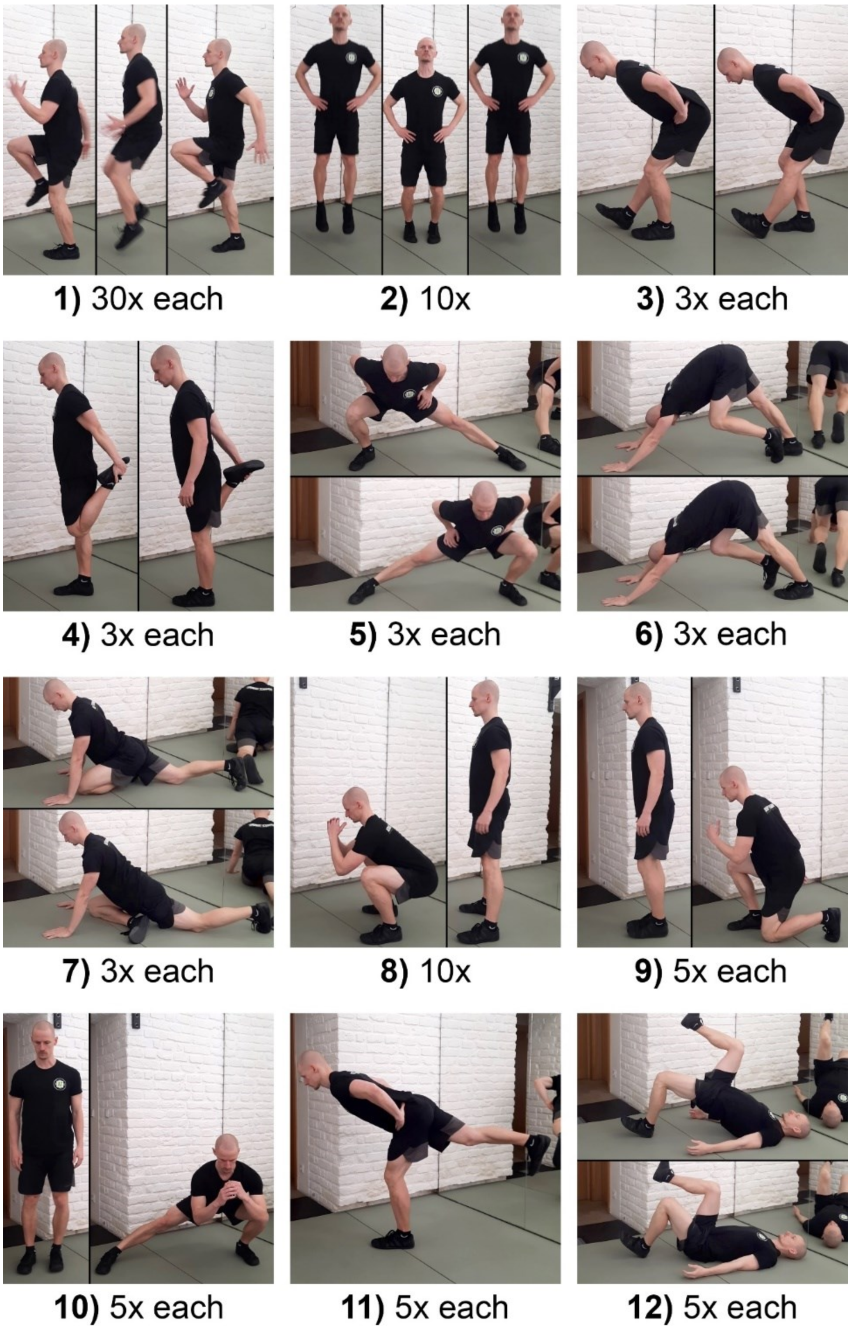


AM = anthropometric measurements (body height, body weight, body fat percentage, and body segments lengths), CMJ = countermovement jump test, EP = experimental protocol (30 repetitions of box or hurdle jumps), FAM = familiarization with EP and rating of perceived exertion, RPE = rating of perceived exertion, RSI = reactive strength index test, WU = warm-up.

Anthropometric Measurements. An electronic column scale (Seca 769; Seca Gmbh & Co. KG., Hamburg, Germany) with fitted stadiometer (Seca 220; Seca Gmbh & Co. KG., Hamburg, Germany) were used to determine participants' body mass and body height, respectively. Body composition, specifically – body fat percentage was determined using direct multi-frequency bioelectrical impedance device (InBody 770, inBody co., ltd., Seoul, South Korea). Additionally, leg length and lower leg length were measured using measuring tape in tall standing position with extended and adducted legs. Leg length was defined as the distance from anterior superior iliac spine to the proximal end of fifth metatarsal on dominant leg and shin length as the distance from the lateral epicondyle to the proximal end of fifth metatarsal on dominant leg. Upper leg length was then calculated as lower leg length subtracted from leg length.

Standardized Warm-Up. Participants performed a single set per exercise of following exercises in this order: 30 ground contacts per leg of in-place running, 10 in place bilateral pogo jumps, dynamic unilateral stretches of hip, knee, and ankle muscles (3 repetitions per leg for each exercise), 10 bodyweight squats, 5 bodyweight reverse lunges per side, 5 bodyweight lateral lunges per side, 5 bodyweight single-legged deadlifts, 5 bodyweight single-legged glut bridges (Figure 5).

Figure 5. Standardized warm-up – first data collection.

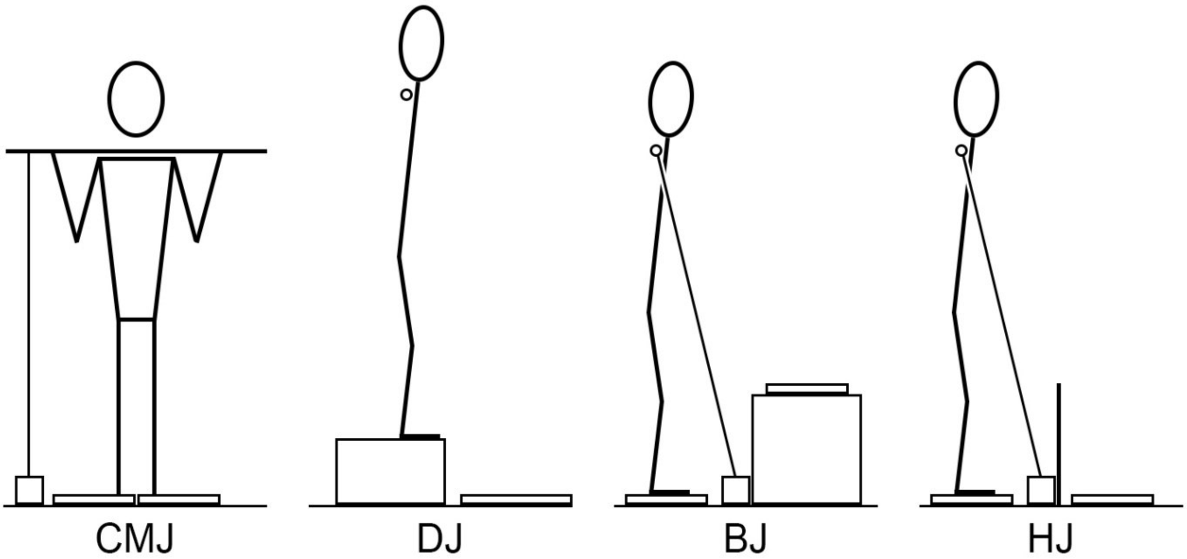


1) 30x each
2) 10x
3) 3x each
4) 3x each
5) 3x each
6) 3x each
7) 3x each
8) 10x
9) 5x each
10) 5x each
11) 5x each
12) 5x each

Countermovement Jump Test. Ten preparatory CMJs with light wooden dowel held behind the base of the neck across the posterior shoulders were performed to provide specific warm-up, to remove any possible positive or negative effects of potentiation on experimental jumps, and to allow participants to familiarize themselves with the experimental setup. The preparatory jumps were immediately followed by 3 maximal CMJs with the same setup. Both preparatory and experimental jumps were performed standing on two three-dimensional piezoelectric force platforms (Kistler 9286BA; Kistler Instruments Inc., Winterthur, Switzerland) positioned side-by-side and synchronized to record as a single platform. The force platforms recorded ground reaction forces using sampling frequency of 1000 Hz, a 16-bit A/D board amplifier, and BioWare software (v5.3.2.9; Kistler Instruments Inc., Winterthur, Switzerland). A custom MATLAB program (v1.8.0.121; MathWorks, Natic, MA, USA) was used to export the data using 20 N threshold to identify individual phases of the jump. Furthermore, a linear position transducer (GymAware Power Tool; Kinetic Performance Technology Pty. Ltd., Canberra, Australia) was used to measure velocity and displacement. The string of the linear position transducer was attached to the wooden dowel 30 cm from the right shoulder towards the end of the dowel and the transducer itself being placed on the ground directly below the end of the string (Hojka et al., 2021). The correct position of the string was checked before every jump. Additionally, one researcher observed the movement of the dowel during the data collection. Any trials with notable rotational dowel movements, deviation from horizontal dowel position, or other cases of failed trial (i.e., hitting the obstacle during the flight or not landing on the force plate) were excluded, and the trial was repeated after completing the prescribed rest interval. The testing setup is depicted in Figure 6. The jumps were performed in 10 second intervals (Miyama & Nosaka, 2007) measured via running timer with acoustic signal (Gymboss miniMax; Gymboss Timers, St. Clair, MI, USA). Preceding pilot testing confirmed this jump frequency to be sufficient and safe in cases when participant missed landing and was forced to step outside the force platform to regain balance. The participants were instructed to jump as high as possible and to land softly. The depth of the countermovement, speed of the countermovement, and stance width were self-selected by the participants to maintain ecological validity. Verbal encouragement from researchers was provided during the experimental jumps.

Reactive Strength Index Test. The RSI was measured during DJ from 30 cm high box with light wooden dowel held across posterior shoulders behind the base of the neck (Figure 6). Two synchronized force platforms positioned side-by-side separated from the box by 5 cm. The force platform hardware and software used to record and extract the ground reaction force data for the RSI test were identical to those described for the CMJ test above. Participants stood in an upright position on top of the box and stepped off by reaching forward with their non-dominant leg. Participants were instructed to prevent jumping up or stepping down from the box. Additionally, participants were instructed to land on the force platform with both feet at the same time and to aim for maximal jump height possible while maximally reducing the ground contact time. Participants were allowed to self-select their countermovement depth and stance width to increase ecological validity. The jump frequency was identical to that described for the CMJ test above. The RSI was calculated as flight time divided by contact time.

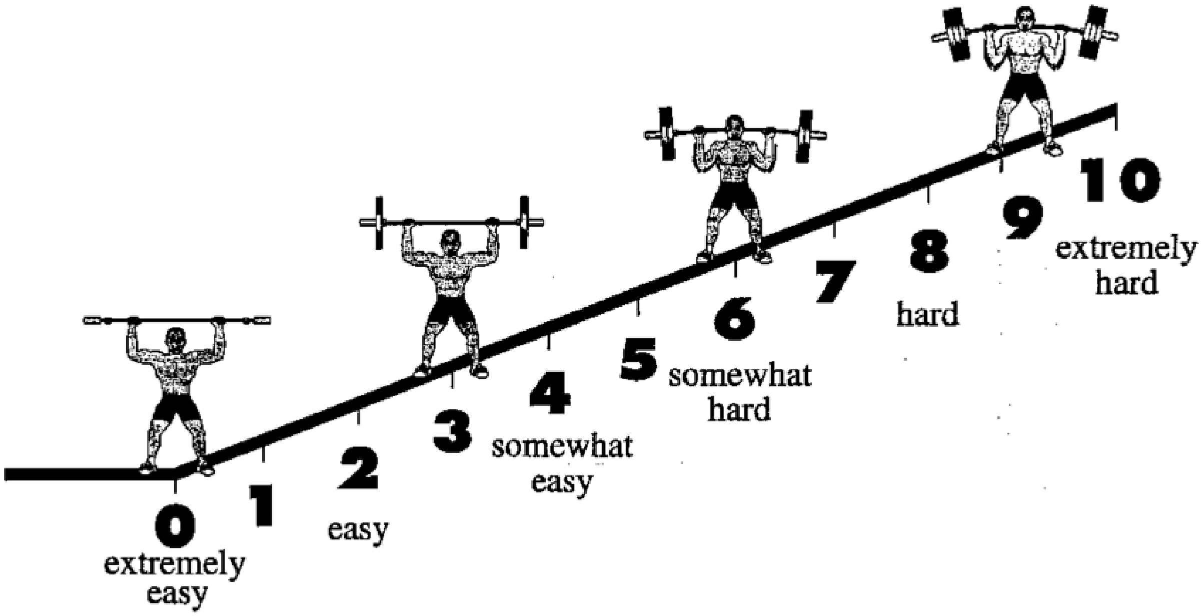
Figure 6. Testing setup – first data collection.



BJ = box jump, CMJ = countermovement jump, DJ = drop jump, HJ = hurdle jump.

Familiarization. All participants were familiarized with BJ and HJ conditions at the end of the initial visit. Each participant performed at least 3 repetitions of BJ and HJ. Additional repetitions were performed when considered necessary by researchers or requested by a participant. Following the familiarization jumps, all participants were familiarized with rating of perceived exertion using 0-10 OMNI-RES scale for adults (Robertson et al., 2003). The OMNI-RES scale for adults in paper form was provided for participants during both familiarization and experimental sessions (Figure 7).

Figure 7. OMNI-RES scale for adults used to determine RPE (Robertson et al., 2003).



Box and Hurdle Jumps. Participants performed 30 repetitions of box jumps onto a 50 cm tall box and 30 repetitions of hurdle jumps over a 50 cm tall hurdle. These two conditions were performed in counterbalanced order on two different days separated by a minimum of 48 hours. Participants assumed tall standing position on top of one force platform (take-off force platform) facing the obstacle with the wooden dowel held in identical position described for the CMJ test above. The nearest edges of both obstacles were positioned 15 cm from the front edge of the take-off force platform. The second (landing) force platform was placed on top of the box 5 cm from the edge closest to the take-off platform. The landing force platform for the hurdle condition was placed on the ground behind the hurdle separated from the hurdle by 5 cm. The vertical distance from the top of the take-off platform to the top of the landing platform placed on the box and to the top of the hurdle was equalized to 50 cm for both conditions. The string of the linear position transducer was attached to the wooden dowel as described above in the CMJ test section; however, for the box jump and hurdle jump conditions the body of the device was placed on the ground on the right side from participants' point of view at the equal distance from the center of both force platforms. This placement was chosen to allow the horizontal displacement of the dowel during the box and hurdle jumps and to account for specific restrictions resulting from the testing setup used during these conditions. The used device captures changes of the string angle to account for its horizontal movement; therefore, it was possible to offset the device placement from the position directly below the dowel without negatively influencing the data. Same as during the CMJ test, participants were allowed to self-select their individually optimal stance width, countermovement depth, and countermovement speed. Furthermore, participants were instructed to achieve the highest possible jump height and to land softly throughout the whole trial. The jumps were performed using jump frequency of 10 seconds which was measured and signalized by automatic timer with acoustic signal (Gymboss miniMax; Gymboss Timers, St. Clair, MI, USA). Participants were instructed to remain at the landing force platform for at least 1 second after landing to regain balance and then to return to the starting position at the take-off force platform by stepping down from the box or stepping over the hurdle and to wait for another acoustic signal. One researcher observed the position and movement of the dowel throughout the whole trial and any repetitions with notable dowel rotation or horizontal tilt were flagged and excluded from the statistical analysis.

Dependent Variables. Ground reaction force data measured via force platforms were used to determine peak take-off forces, rate of force development, total impulsion time, and peak impact force. Peak take-off forces in vertical (PF-v), horizontal (PF-h), and resultant (PF-r) directions were calculated as the maximal force produced in each direction from the initiation of the countermovement to the moment of take-off. Average rate of force development during take-off phase (RFD) was calculated as PF-r divided by the time to achieve PF-r (Haff et al., 2015). Total impulsion time was calculated as duration from the initiation of the countermovement to the moment of take-off. Peak landing forces were calculated as the maximal force produced in resultant (IF-r) and vertical (IF-v) direction during the landing. The internal software of the linear position transducer was used to determine countermovement depth as maximal downward displacement of the dowel below the upright standing position during the take-off phase, mean and peak concentric velocity, time to peak concentric velocity, peak concentric power, time to peak concentric power, and jump height.

6.2.2 Second data collection

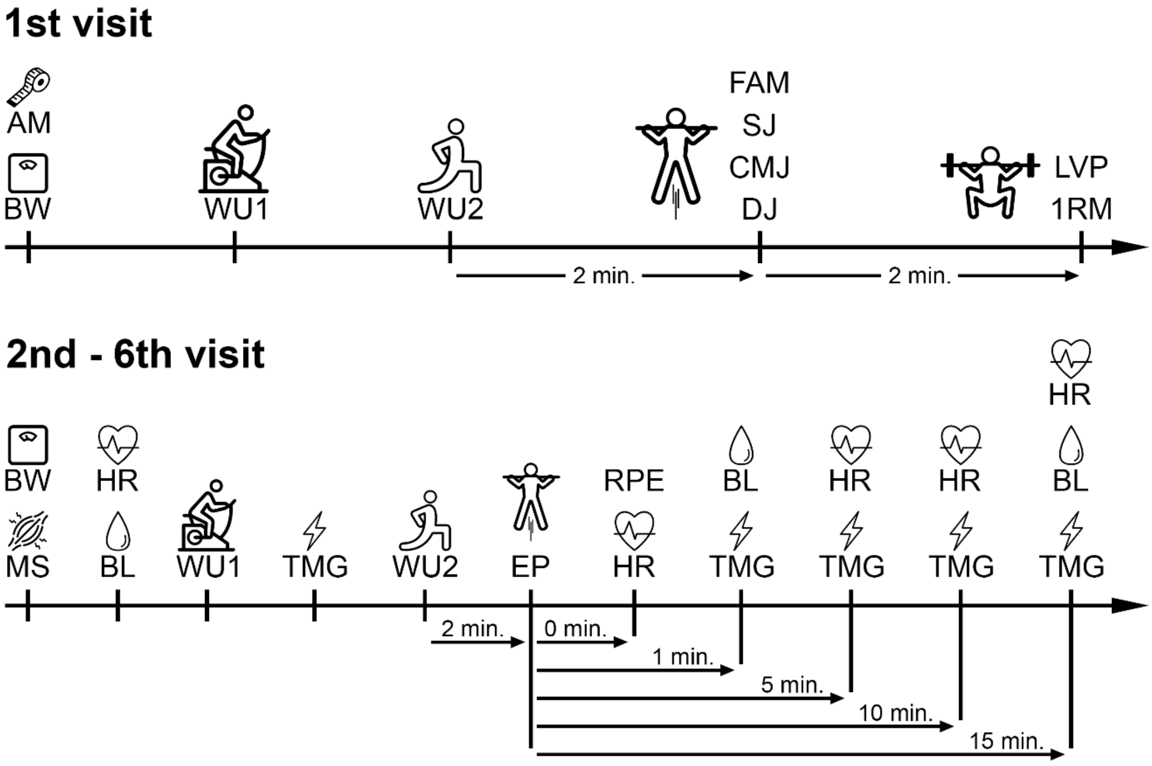
Participants performed 50 maximal effort CMJs with various inter-repetition rest durations on 5 non-consecutive days separated by at least 48 hours to prevent any carry-over effect of fatigue. The jumps were performed continuously (R0c; whereby the end of one jump immediately transitioned into the next jump) or intermittently with 0 (R0i; where they landed, stood upright, and then began the next countermovement), 4 (R4), 8 (R8), and 12 (R12) seconds of inter-repetition rest in counter-balanced quasi-randomized order. The time of the day was kept constant for each participant (±1 h). All participants provided informed consent before being enrolled in the experiment. Anthropometric measurements, standardized warm-up, familiarization with the experimental procedure, vertical jump testing including SJ, CMJ and

DJ, load-velocity profile, and one repetition maximum (1RM) test for back squat exercise were completed at least 48 h before the first experimental session in this order. Each experimental session began with bodyweight measurement and muscle soreness assessment. Followed by baseline heart rate and blood lactate concentration measurements, warm-up on bicycle ergometer, baseline tensiomyography (TMG) measurement, and second part of warm-up including dynamic stretching, calisthenic, and plyometric exercises. Participants then performed an experimental procedure (50 CMJs) throughout which heart rate as well as multiple linear performance-related kinetic parameters were recorded. After completing the experimental protocol, participants immediately assumed supine lying position on the nearby massaging table and remained in this position until competition of all post-exercise measurements. These included RPE assessment (0 minutes after), heart rate (0, 5, 10, and 15 minutes after), blood lactate concentration (1, 5, 10, and 15 minutes after), and TMG (1, 5, 10, and 15 minutes after) measurements. Figure 8 contains the flowchart of experimental protocol.

Anthropometric Measurements. Similar to the first data collection, body weight and body height of participants were measured using digital column scale with integrated stadiometer (Seca 769 and Seca 220; Seca Gmbh & Co. KG., Hamburg, Germany). Direct multi-frequency bioelectrical impedance device (InBody 770; inBody co., ltd., Seoul, South Korea) was used to measure body composition in fasted state (≥2 hours). Additionally, leg lengths were measured using measuring tape in supine lying position with extended and adducted legs as the distance from anterior superior iliac spine to the medial malleolus for each leg. Leg length discrepancy was then calculated by subtracting length of shorter leg from length of longer leg.

Standardized Warm-Up. Warm-up consisted of two parts. The first part included cycling on a stationary ergometer (duration = 5 minutes, resistance = 100 W, cadence = 60 rpm). The second part included 6 dynamic lower body stretching exercises (focused on hip flexors, hip extensors, hip adductors, hip abductors, knee flexors, knee extensors, and ankle plantar flexors) performed unilaterally with 5 repetitions per side. Furthermore, each participant performed 10 bodyweight squats, 5 forward lunges per side, 5 unilateral glute bridges per side, 10 pogo jumps, 5 intermittent CMJs, and 3 continuous CMJs, in this order (Figure 9). The warm-up was followed by 2 minutes of rest.

Figure 8. Experimental protocol – second data collection.



1RM = back squat 1 repetition maximum test, AM = anthropometric measurements (body height, body fat percentage, and leg lengths), BL = blood lactate concentration, BW = body weight, CMJ = countermovement jump test, DJ = drop jump test, EP = experimental protocol (50 repetitions with R0c, R0i, R4, R8, or R12), FAM = familiarization with EP and rating of perceived exertion, HR = heart rate, LVP = back squat load-velocity profile, MS = muscle soreness assessment, RPE = rating of perceived exertion, SJ = squat jump test, TMG = tensiomyography of m. quadratus lateralis, WU1 = bicycle ergometer warm-up, WU2 = dynamic stretching and calisthenics warm-up.

Familiarization. Participants were familiarized with the experimental procedure during the initial session. Familiarization was completed after standardized warm-up, but before vertical jump test and consisted of 1-3 repetitions of squat jump, CMJ, and drop jump, respectively. This timing of familiarization was chosen because testing setup for CMJ test was identical to that used during the experimental protocol. Familiarization with setup for back squat LVP and 1RM tests was undertaken following the vertical jump testing. Finally, familiarization with rating of perceived exertion using 0-10 OMNI-RES scale for adults (Robertson et al., 2003) was performed following the back squat 1RM test concluding the initial visit. The OMNI-RES scale for adults in paper form was provided for participants during both familiarization and experimental sessions (Figure 7).

Vertical Jump Test. Maximal SJ, CMJ, and DJ in this order, for three repetitions each, were performed to test the jumping ability of participants (Figure 10). Participants rested approximately 15 seconds between repetitions within single jump variation and 1 minute between jump variations. Jump height was measured by 2 linear position transducers (GymAware Power Tool; Kinetic Performance Technologies, Canberra, Australia) attached to a light wooden dowel (one on each side) held horizontally across the posterior shoulders behind the base of the neck. linear position transducers were positioned on the ground, so the theaters were in vertical position before initiating each jump. The results from both linear position transducers were averaged to prevent any potential measurement errors caused by uneven or rotational movements of the dowel. The used device captures changes of the string angle to account for its horizontal movement; therefore, potential horizontal shifts or rotational movements of the dowel would not influence the data. The highest of 3 repetitions was included in the analysis. Participants were instructed to jump as high as possible on every repetition. Participants were required to hold bottom position (knee angle <90 degrees) during the SJ for at least 2 seconds (indicated by researchers) before initiating the upward movement. In case any additional countermovement directly preceding upward motion was detected during the SJ, the repetition was discarded. In case 2 or more repetitions of the SJ were not performed correctly, additional repetition was performed. For the CMJ participants started in the upright standing position and after being signaled by the researchers, performed countermovement followed by the upward motion without any pause at the bottom of the countermovement. The countermovement depth during the CMJ test was self-selected by each participant. The DJ was performed after a step-off from a 32 cm high box using preferred leg. Participants were instructed to contact the ground with both feet at the same time and to use countermovement depth similar to that used during the preceding CMJ test. The stance width for all vertical jump tests was self-selected by each participant to increase ecological validity.

Figure 9. Standardized warm-up – second data collection.

1) 5x each

2) 5x each

3) 5x each

4) 5x each

5) 5x each

6) 5x each

7) 10x

8) 5x each

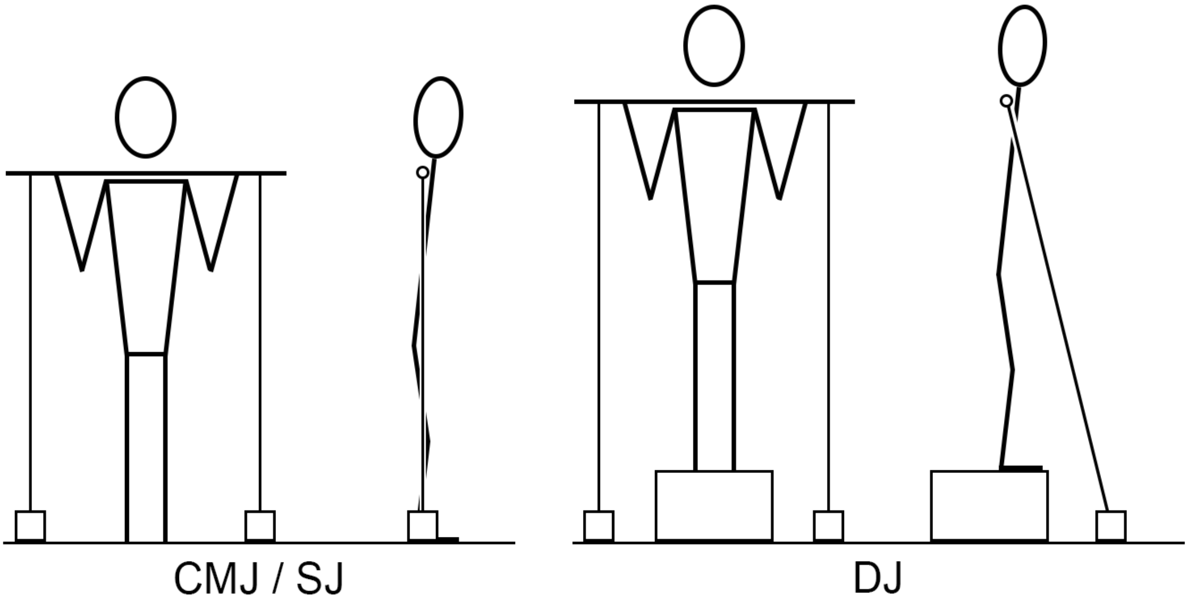
9) 5x

10) 10x

11) 5x intermittent

12) 3x continuous

Figure 10. Testing setup – second data collection.



CMJ = countermovement jump, DJ = drop jump, SJ = squat jump.

Load-Velocity Profile and 1RM Back Squat Test. Participants performed warm-up consisting of 5 repetitions of back squat with 20 kg barbell and followed by 1-2 optional warm-up sets if required. Simultaneously these 5 to 15 warm-up repetitions served as familiarization with the testing setup. Participants rested for 1 minute and then performed back squats with increasing load with intention to achieve maximal concentric velocity with every load. Two repetitions per load were performed for 20, 40 and 60 % of estimated back squat 1RM, and 1 repetition for 80 and 90 % of estimated back squat 1RM. Each participant estimated his back squat 1RM load based on their recent training history. Individual loads were separated by 3 minutes of passive rest. Squat depth and bar position were individualized based on each participant's individual preference; however, they had to be kept consistent for each load and knee angle at the bottom of the squat had to be smaller than 90 degrees. Participants were allowed to self-select the eccentric tempo. Then they performed the concentric phase as fast as possible without any pause at the bottom of the movement. Participants were not allowed to jump at the end of the concentric phase. In case of any failed repetitions (i.e., due to loss of balance, technical error, insufficient squat depth, or loss of ground contact at the end of the concentric phase) one additional repetition was allowed after completing 3 minutes of rest. After completing the load equal to 90 % of estimated back squat 1RM, each participant self-selected further load increments until the true 1RM load was reached. The bar velocity was measured using linear position transducers attached to each end of the barbell and the averaged value was recorded to prevent any potential measurement errors caused by uneven movements of the barbell. Repetition with faster mean concentric velocity was analyzed for loads with multiple repetitions.

Heart Rate. A surface heart rate sensor strapped around a participant's chest (Polar H10, Polar Electro Oy, Kempele, Finland) was used to collect heart rate data. The baseline heart rate was measured in supine lying position. Participants were lying quietly for 5 minutes. The baseline heart rate was determined as an average heart rate during the last 3 minutes. Pre-intervention value was reported as absolute value 1 second before the start of the experimental intervention. heart rate was also recorded continuously during the whole intervention and recovery period. The heart rate recorded during the experimental protocol is presented as an average value for each grouping of 5 consecutive repetitions. The heart rate recorded during the recovery period is presented as absolute values recorded at 0-, 5-, 10-, and 15-minute after completing the experimental protocol.

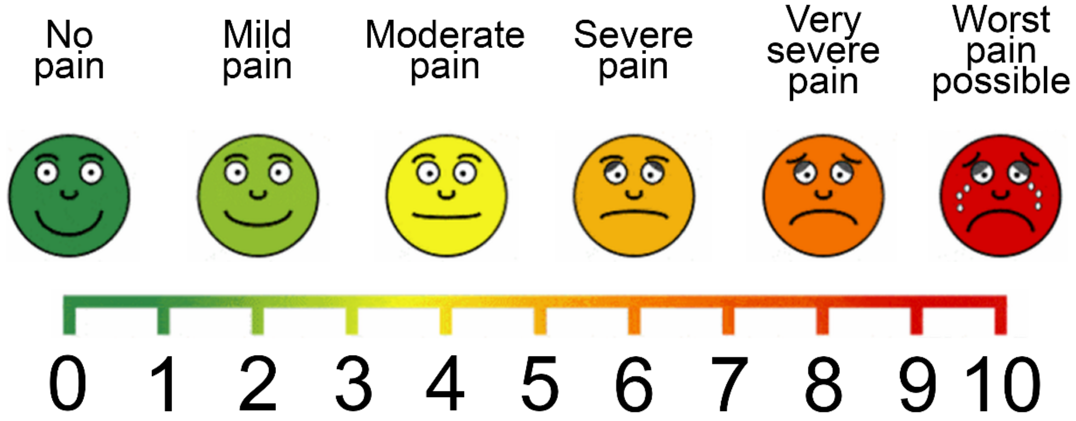
Blood Lactate Concentration. The baseline blood lactate concentration was measured in supine lying position immediately after the baseline heart rate measurement from a 0.3 µl sample of capillary blood taken from a fingertip and analyzed using a portable device (Lactate Pro2, ARKRAY Inc., Kyoto, Japan). Blood lactate concentration was measured again at 1- and 15-minutes after completing the experimental protocol.

Tensiomyography. Localized contractile properties of the dominant leg vastus lateralis were measured using non-invasive tensiomyograph (TMG-BMC Ltd., Ljubljana, Slovenia) which has been shown reliable and valid for this purpose (Macgregor et al., 2018). The dominant leg was reported by each participant as their preferred jumping leg. Participants assumed relaxed supine lying position with a knee angle of 150° (180° = full extension) supported by the original platform from the device manufacturer. Then the position of the stimulating electrodes and the tensiomyograph sensor were measured according to the SENIAM guidelines for electromyography and marked for consistent placement in the following experimental sessions. The sensor was placed at 2/3 on the line from the anterior superior iliac spine to the lateral border of patella. The electrodes were placed 2 cm proximally and 2 cm distally to the sensor in the direction of the vastus lateralis muscle fibers. The muscle contractile properties were assessed using a digital sensor which measured the radial displacement of muscle belly during a twitch contraction induced by a 1 millisecond monophasic electrical impulse. The progressive stimulation of the muscle started at the intensity of 30 mA and continued with 10 mA increments until no further changes of the time-displacement curve were registered. The baseline TMG measurement was performed immediately after completing the first part of the warm-up and the procedure was repeated at 1-, 5-, 10- and 15-minutes after completing the experimental protocol. The measured variables included: maximal amplitude of muscle belly displacement (TMG-Dm) and contraction time (TMG-Tc, the time between 10% and 90% of TMG-Dm).

Rating of Perceived Exertion. Participants were asked to rate their perceived exertion immediately after the last jump of the experimental protocol using visual analogue 0 (extremely easy) to 10 (extremely hard) OMNI-RES scale for adults (Robertson et al., 2003). Figure 6 presents the OMNI-RES scale for adults used in this experiment.

Muscle Soreness. Participants provided a subjective rating of lower extremities muscle soreness perceived while performing bodyweight squat. An eleven-point visual analogue scale ranging from 0 (no pain) to 10 (worst pain possible) was used for this purpose (Figure 11). In case of excessive level of perceived muscle soreness (>4), additional day of rest was provided.

Figure 11. Visual analogue scale used for rating of perceived muscle soreness.



Experimental Protocol. The experimental protocol consisted of 50 CMJs performed with the light wooden dowel held across the shoulders with attached linear position transducers as described for the CMJ test above. Participants were instructed to perform all jumps with the intention to reach the maximum possible jump height and concentric velocity. To do so, verbal encouragement was provided by the researchers throughout the whole protocol. Participants were allowed to use self-selected countermovement depth and stance width. No music was played, and no female researchers were present during the experimental protocol to limit the number of possible confounding factors. Additionally, all researchers were positioned behind participants to ensure there was no motion in their line of sight during the intervention. The jumps were performed either continuously (R0c) or intermittently with 0 (R0i), 4 (R4), 8 (R8) and 12 (R12) seconds of inter-repetition rest in quasi-randomized counterbalanced order on separate days. The order of the protocols was pre-determined and printed before the beginning of the data collection. The participants were instructed to return to an upright standing position as soon as they regained stability after the landing during the intermittent protocols. The start of the inter-repetition rest period was defined as the moment when the participant's knees reached full extension. The end of the rest period was indicated by an acoustic signal. Information about the number of completed jumps was provided for the participants continuously throughout the experimental protocol. Once the final jump was completed, one researcher helped participants with transferring onto the nearby massaging table for post-intervention measurements. Simultaneously, another researcher asked participants about their momentarily RPE value. Countermovement depth (maximal vertical displacement below upright standing position during take-off phase), maximal horizontal displacement (from upright standing position in each direction during the whole repetition), mean concentric velocity, peak concentric velocity, time to peak concentric velocity, mean eccentric velocity, minimal eccentric velocity, and jump height (maximal vertical displacement above upright standing position) were measured via linear position transducers.

6.3 Statistical analysis

6.3.1 First data collection

Data collected during the 30 repetitions of BJ and HJ were split into 5 groupings of 6 repetitions (G1-G5) and mean values for each grouping of repetitions were compared for each dependent variable. Furthermore, repetitions number 11, 12, and 13 from both BJ and HJ conditions were averaged and compared to averaged values of CMJ test. The Quantile-Quantile plots were used to test the data for normality of distribution. Mean and standard deviation (SD) was calculated for all dependent variables. One-way (for RPE and CMJ vs. BJ vs. HJ comparisons) and two-way (for exercise volume: G1, G2, G3, G4, G5 × condition: BJ vs. HJ) repeated measures ANOVAs were performed to assess the data. A Greanhouse-Geisser correction was used in the instances where the sphericity was not assumed. Post hoc pairwise comparisons using Bonferroni correction were performed when appropriate. Significance level for all tests was set at $p \leq 0.05$. Cohen's f with two-sided 95 % confidence intervals were used to calculate effect sizes for ANOVA. Cohen's d effect size with two-sided 95 % confidence intervals was used for post hoc pairwise comparison when appropriate. The Cohen's f effect size results are interpreted as negligible (< 0.10), small (0.10 to 0.24), moderate (0.25 to 0.39), and large (≥ 0.40) (Cohen, 1988); and Cohen's d effect sizes are interpreted as trivial (< 0.20), small (0.20 to 0.49), moderate (0.50 to 0.79), and large (≥ 0.80) (Cohen, 1988). The one-way consistency single score intra-day intraclass correlation coefficients with 95 % confidence intervals were calculated for CMJ, BJ, and HJ jump types; these will be interpreted as poor (< 0.50), moderate (0.50 to 0.74), good (0.75 to 0.90), and excellent (> 0.90) reliability (Koo & Li, 2016). Lastly, Pearson's product moment correlation coefficient (r) was used to test for association between anthropometric characteristics (body height, body weight, body fat percentage, leg length, upper leg length, and lower leg length) and variables measured during the three jump types (countermovement depth, IF-v, IF-r, jump height, mean concentric velocity, peak concentric velocity, time to peak concentric velocity, peak concentric power, time to peak concentric power, PF-h, PF-v, PF-r, RFD, and total impulsion time). Spearman's rank correlation coefficient (r_s) was used in case of non-normal data distribution (Field et al., 2012). For the purposes of correlation analysis, PF-h, PF-v, PF-r, IF-v, and IF-r values were converted to values relative to participant's body weight and leg length, upper leg length, and lower leg length were converted to percentage of participant's body height. The results of correlation analysis will be interpreted as negligible (−0.09 to 0.09), weak (−0.39 to −0.10 and 0.10 to 0.39), moderate (−0.69 to −0.40 and 0.40 to 0.69), strong (−0.89 to −0.70 and 0.70 to

0.89), and very strong (−1.00 to −0.90 and 0.90 to 1.00) correlation (Schober et al., 2018). RStudio 2023.06.1+524 (Integrated Development Environment for R; RStudio, PBC, Boston, MA, USA) was used to perform all statistical analyses.

6.3.2 Second data collection

The variables measured across the 50 jump repetitions are analyzed and reported as mean values for 10 groups of 5 consecutive CMJ repetitions (G1-G10). G1 for mean and minimal eccentric velocity in R0c protocol were calculated as average of second to fifth repetition to prevent distortion resulting from slower countermovement of the initial jump. Normality of distribution was assessed via Quantile-Quantile plot. 5 (protocol) × 10 (exercise volume) two-way repeated measures ANOVA was used for countermovement depth, mean concentric velocity, peak concentric velocity, mean eccentric velocity, minimal eccentric velocity, horizontal displacement, jump height, and time to peak concentric velocity. Furthermore, heart rate was analyzed by 5 (protocol) × 16 (time), blood lactate concentration by 5 (protocol) × 3 (time), and TMG-Dm and TMG-Tc by 5 (protocol) × 5 (time) two-way repeated measures ANOVA. Greenhouse-Geisser correction was used for analyses where sphericity assumption was not met. One-way ANOVA was used to analyze differences in bodyweight, muscle soreness, RPE, and protocol durations between experimental protocols. Partial eta-squared (η_p^2) effect size was calculated and interpreted according to the criteria suggested by Cohen as trivial (< 0.01), small (0.01 to 0.05), moderate (0.06 to 0.13), and large (≥ 0.14) (Cohen, 1988). Pairwise comparisons using Bonferroni post hoc corrections were performed when appropriate, alongside with calculating paired Hedge's g effect sizes which were interpreted as trivial (< 0.20), small (0.20 to 0.49), moderate (0.50 to 0.79), large (≥ 0.80) using Cohen's criteria (Cohen, 1988). Finally, relationship between effects of continuous 50 CMJs and anthropometric characteristics (body height, body weight, body fat, leg length, leg length discrepancy), training experience, as well as performance characteristics (absolute and relative lower body strength, slope of load-velocity profile, jumping performance, and amount of stretch-shortening cycle potentiation during vertical jumps). Initially, we performed pairwise correlation tests to identify significant relationships in the entire sample using the same approach as described for the first data collection above. This was followed by subgroup analysis, where the sample was split into multiple subgroups based on the performance characteristics listed above. Each subgroup included 6 participants of either top or bottom performing individuals. Two participants with median values for each parameter were not included in the analysis. Statistical power was calculated via post hoc independent means difference for each dependent parameter across all subgroups using G*Power 3.1 (RRID:SCR_013726; G-Power, Brunsbüttel, Germany). Independent samples t-test and Hedge's g effect size were used to analyze differences between subgroups as well as changes in dependent variables in response to 50 continuous CMJs. Significance level for all tests was set at $p \leq 0.05$. Results are reported as mean ± SD. Due to the large number of comparisons, only the most important significant interactions, particular p values, and effect sizes are described in the text. The statistical analysis was performed using RStudio 2023.06.1+524 (Integrated Development Environment for R; RStudio, PBC, Boston, MA, USA).

7 Results

7.1 Take-off and landing parameters

Most of the variables have shown moderate to good reliability, except for excellent reliability for countermovement depth during all three jump types, and excellent reliability for PF-r, PF-v, and RFD during BJ (Figure 12). A total of 5 trials had to be discarded and repeated (3 CMJs, 1 HJ, and 1 BJ) due to an extensive dowel movement (4 trials) or missing the force platform upon landing (1 trial).

There were non-significant small to moderate effects of jump type on mean concentric velocity ($F_{2,38} = 0.93$, $p = 0.403$, $f = 0.22$ [0.00 to 0.50]), peak concentric velocity ($F_{2,38} = 2.724$, $p = 0.078$, $f = 0.38$ [0.00 to 0.68]), PF-r ($F_{2,38} = 1.873$, $p = 0.168$, $f = 0.31$ [0.00 to 0.61]), PF-v ($F_{2,38} = 1.356$, $p = 0.27$, $f = 0.27$ [0.00 to 0.55]), RFD ($F_{2,38} = 0.731$, $p = 0.488$, $f = 0.20$ [0.00 to 0.47]), and total impulsion time ($F_{2,38} = 2.883$, $p = 0.068$, $f = 0.39$ [0.00 to 0.69]). On the other hand, jump type has shown to have significant large effects on countermovement depth ($F_{1.46,27.67} = 5.871$, $p = 0.013$, $f = 0.56$ [0.17 to 0.88]), peak concentric power ($F_{2,38} = 8.456$, $p < 0.001$, $f = 0.67$ [0.28 to 1.00]), time to peak concentric power ($F_{2,38} = 7.75$, $p = 0.002$, $f = 0.64$ [0.25 to 0.97]), time to peak concentric velocity ($F_{1.52,28.8} = 12.362$, $p < 0.001$, $f = 0.81$ [0.41 to 1.16]), PF-h ($F_{2,38} = 184.966$, $p < 0.001$, $f = 3.12$ [2.34 to 3.88]), jump height ($F_{2,38} = 54.35$, $p < 0.001$, $f = 1.69$ [1.18 to 2.17]), IF-r ($F_{2,38} = 72.924$, $p < 0.001$, $f = 1.96$ [1.40 to 2.49]), and IF-v ($F_{2,38} = 70.688$, $p < 0.001$, $f = 1.93$ [1.38 to 2.45]). Means ± SDs for all dependent variables and results of post hoc tests where warranted are presented in Figures 13-16.

Figure 12. Intraclass correlation coefficients with 95 % confidence intervals for all dependent variables and jump types.

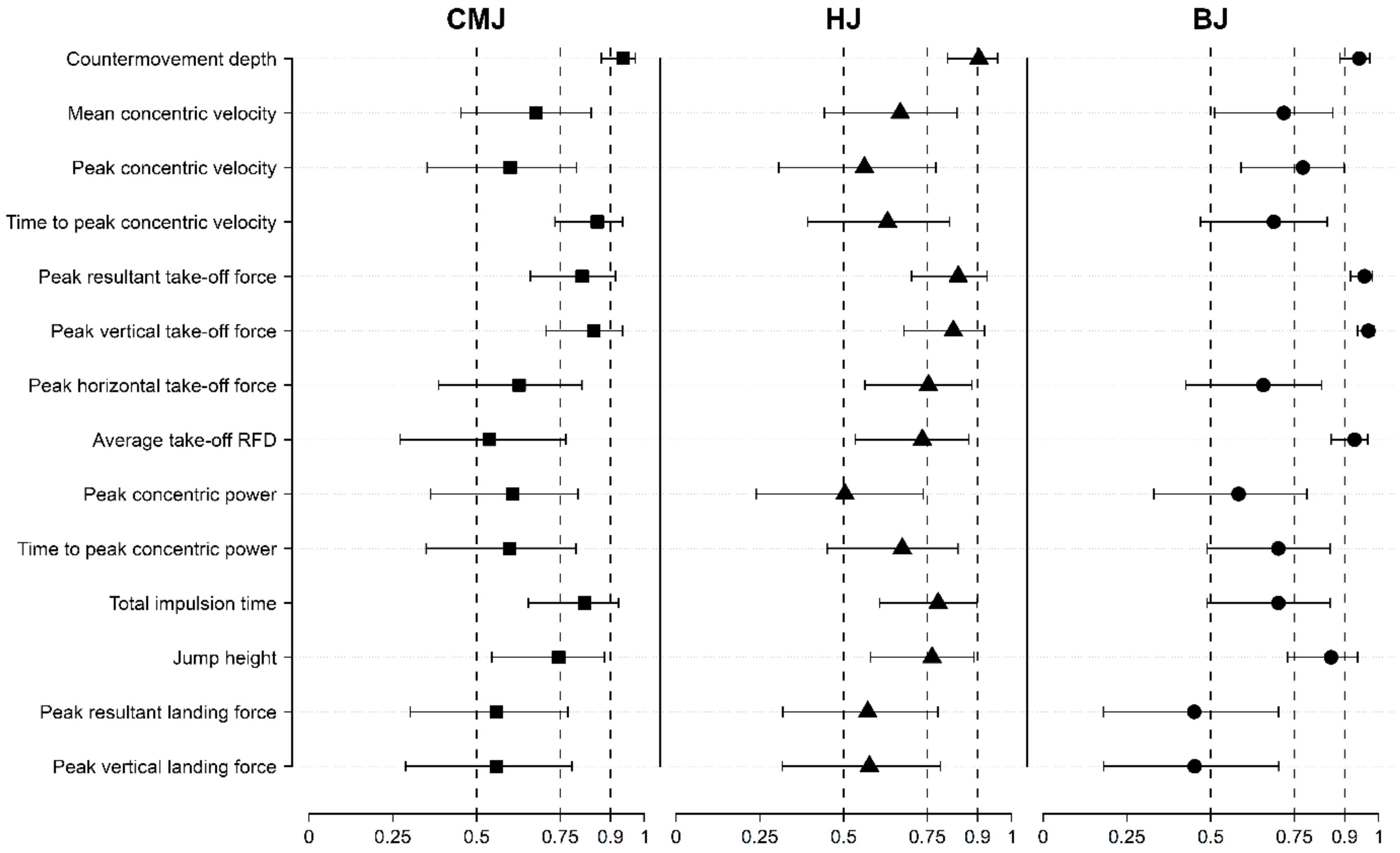
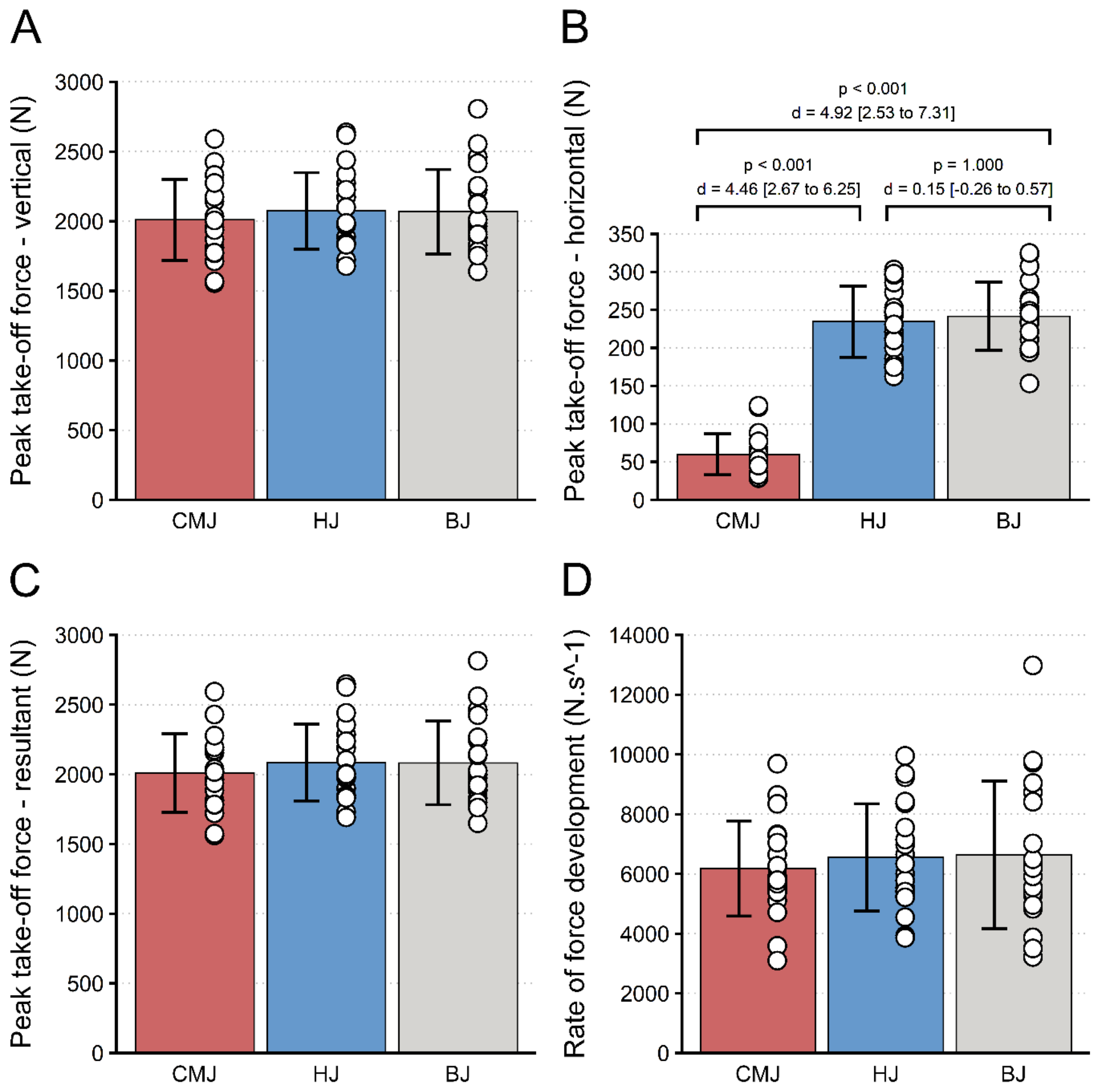
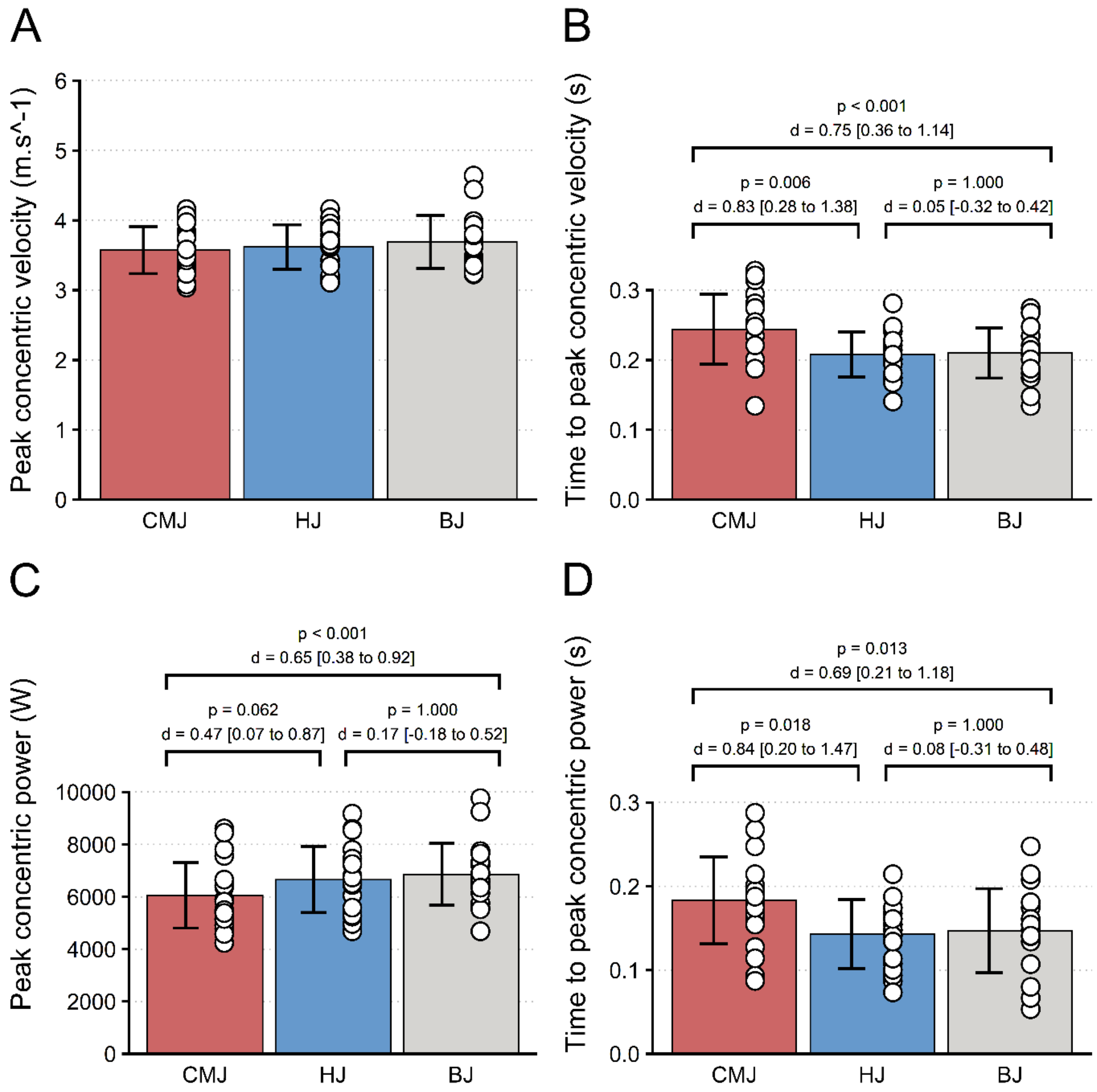


Figure 13. Mean ± SD and results of post hoc tests for A) peak horizontal take-off force, B) peak vertical take-off force, and C) peak resultant take-off force, and D) average take-off rate of force development.



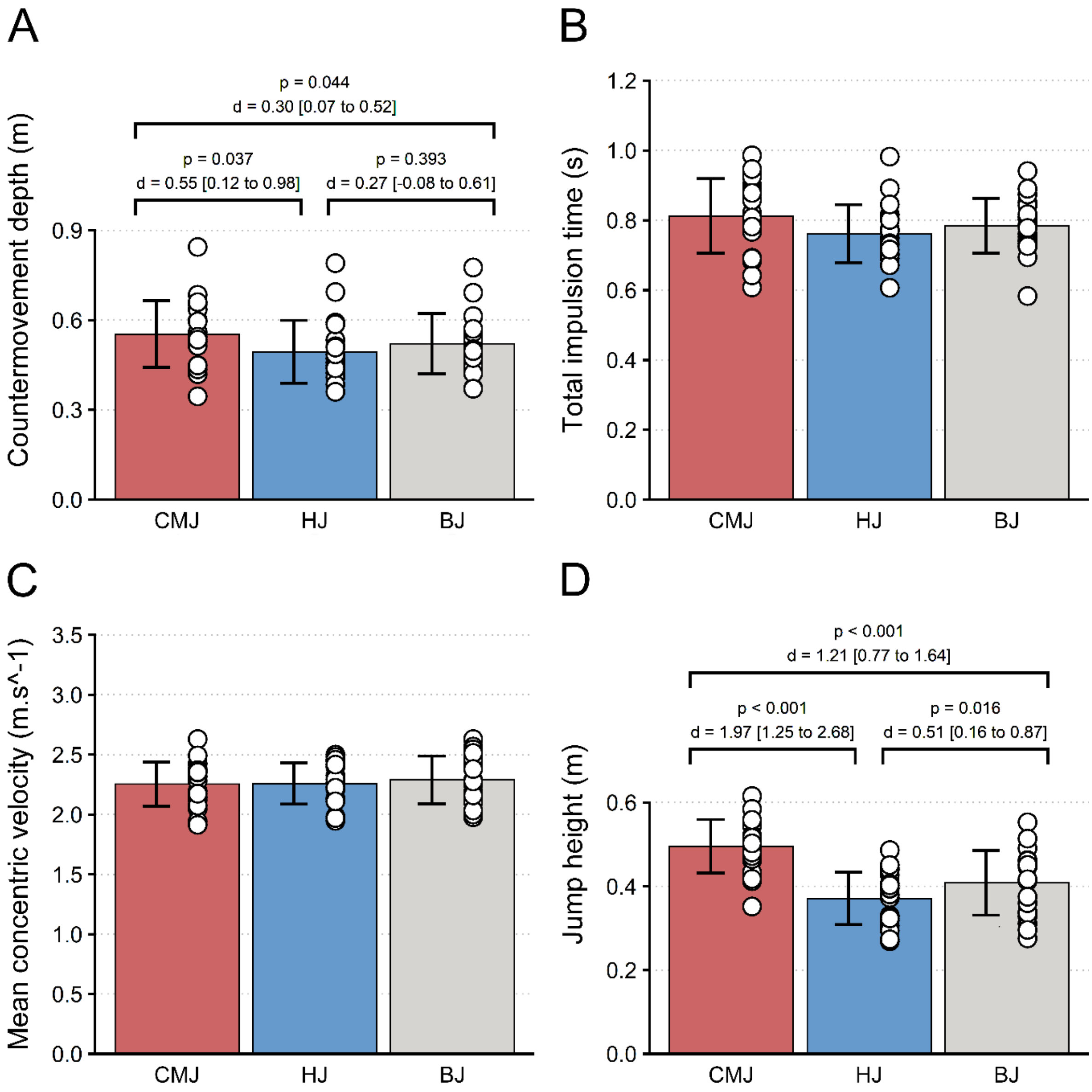
BJ = box jump, CMJ = countermovement jump, HJ = hurdle jump, p = probability value resulting from post hoc pairwise comparison, d = Cohen's d effect size with 95 % confidence interval.

Figure 14. Mean ± SD and results of post hoc tests for A) peak concentric velocity, B) time to peak concentric velocity, C) peak concentric power, and D) time to peak concentric power.



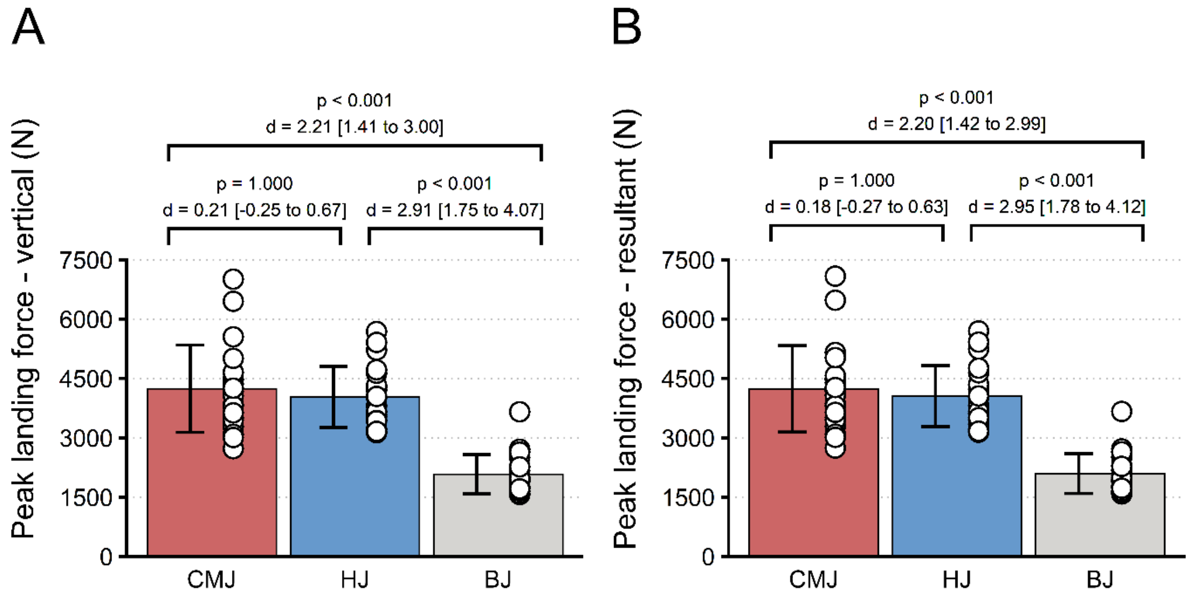
BJ = box jump, CMJ = countermovement jump, HJ = hurdle jump, p = probability value resulting from post hoc pairwise comparison, d = Cohen's d effect size with 95 % confidence interval.

Figure 15. Mean ± SD and results of post hoc tests for A) countermovement depth, B) total impulsion time, C) mean concentric velocity, and D) jump height.



BJ = box jump, CMJ = countermovement jump, HJ = hurdle jump, p = probability value resulting from post hoc pairwise comparison, d = Cohen's d effect size with 95 % confidence interval.

Figure 16. Mean ± SD and results of post hoc tests for A) peak vertical landing force and B) peak resultant landing force.



BJ = box jump, CMJ = countermovement jump, HJ = hurdle jump, p = probability value resulting from post hoc pairwise comparison, d = Cohen's d effect size with 95 % confidence interval.

7.2 Magnitude of landing forces

Tables 11 and 12 provide means and standard deviations for all dependent variables measured across 30 repetitions of BJ and HJ conditions. Table 13 summarizes ANOVA and effect size results. The results show no significant condition × exercise volume interaction for all dependent variables. However, there was significant large effect of condition for IF-v, jump height, mean concentric velocity, and peak concentric velocity (Table 13). Additionally, there was a significant large effect of exercise volume for mean concentric velocity, peak concentric velocity, countermovement depth, RFD, PF-v, and peak concentric power (Table 13). No significant effect of condition or exercise volume was observed for time to peak concentric velocity and time to peak concentric power. Post hoc pairwise comparison revealed that mean concentric velocity, peak concentric velocity, countermovement depth, RFD, PF-v, and peak concentric power were significantly lower during G1 compared to most of the following repetition groups (Tables 11 and 12). Reported RPE values (BJ = 4.55 ± 1.23, HJ = 4.60 ± 1.19) did not differ between the experimental conditions ($F_{1,19} = 0.03$, $p = 0.87$, $f = 0.04$ [0.00 to 0.27]).

Table 11. Mean ± standard deviation and post hoc pairwise comparison of linear position transducer data across 30 box and hurdle jumps.

		G1	G2	G3	G4	G5	Total
CMD (m)	**BJ**	0.500 ± 0.096	0.518 ± 0.103	0.526 ± 0.101	0.523 ± 0.102	0.533 ± 0.096	0.520 ± 0.100
	HJ	0.475 ± 0.108	0.498 ± 0.102	0.497 ± 0.114	0.499 ± 0.119	0.509 ± 0.122	0.496 ± 0.113
	Total	0.488 ± 0.103	0.508 ± 0.103 *	0.512 ± 0.109 *	0.511 ± 0.111	0.521 ± 0.110 *	–
MCV (m·s^{-1})	**BJ**	2.212 ± 0.217	2.282 ± 0.222	2.308 ± 0.205	2.311 ± 0.221	2.332 ± 0.216	2.289 ± 0.220
	HJ	2.151 ± 0.239	2.254 ± 0.209	2.247 ± 0.198	2.268 ± 0.188	2.261 ± 0.191	2.236 ± 0.210 †
	Total	2.182 ± 0.230	2.268 ± 0.216 *	2.278 ± 0.203 *	2.289 ± 0.206 *	2.296 ± 0.207 *	–
PCV (m·s^{-1})	**BJ**	3.561 ± 0.380	3.661 ± 0.391	3.696 ± 0.369	3.697 ± 0.397	3.710 ± 0.410	3.665 ± 0.392
	HJ	3.441 ± 0.420	3.601 ± 0.347	3.643 ± 0.369	3.610 ± 0.353	3.625 ± 0.363	3.584 ± 0.377 †
	Total	3.501 ± 0.404	3.631 ± 0.371 *	3.670 ± 0.369 *	3.654 ± 0.377 *	3.667 ± 0.388 *	–
TTPCV (s)	**BJ**	0.214 ± 0.035	0.209 ± 0.039	0.211 ± 0.041	0.211 ± 0.040	0.209 ± 0.041	0.211 ± 0.039
	HJ	0.207 ± 0.033	0.207 ± 0.036	0.207 ± 0.038	0.205 ± 0.039	0.210 ± 0.043	0.207 ± 0.038
	Total	0.211 ± 0.034	0.208 ± 0.037	0.209 ± 0.040	0.208 ± 0.040	0.210 ± 0.042	–
PCP (W)	**BJ**	6394.4 ± 1377.4	6748.7 ± 1271.9	6920.7 ± 1461.4	7013.7 ± 1720.5	6938.9 ± 1710.3	6803.3 ± 1530.1
	HJ	6112.0 ± 1504.3	6537.3 ± 1333.8	6743.7 ± 1534.3	6668.7 ± 1447.0	6799.9 ± 1643.5	6572.3 ± 1511.3
	Total	6253.2 ± 1446.1	6643.0 ± 1304.8 *	6832.2 ± 1497.8 *	6841.2 ± 1595.7 *	6869.4 ± 1675.2 *	–
TTPCP (s)	**BJ**	0.154 ± 0.050	0.148 ± 0.053	0.150 ± 0.053	0.151 ± 0.051	0.145 ± 0.051	0.150 ± 0.052
	HJ	0.146 ± 0.042	0.147 ± 0.043	0.149 ± 0.046	0.144 ± 0.053	0.156 ± 0.053	0.149 ± 0.048
	Total	0.150 ± 0.047	0.147 ± 0.048	0.150 ± 0.049	0.148 ± 0.052	0.151 ± 0.052	–
JH (m)	**BJ**	0.390 ± 0.079	0.404 ± 0.076	0.403 ± 0.080	0.401 ± 0.081	0.402 ± 0.082	0.400 ± 0.079
	HJ	0.361 ± 0.071	0.372 ± 0.071	0.377 ± 0.079	0.375 ± 0.085	0.379 ± 0.091	0.373 ± 0.080 †
	Total	0.375 ± 0.076	0.388 ± 0.075	0.390 ± 0.080	0.388 ± 0.084	0.390 ± 0.087	–

*BJ = box jump, CMD = countermovement depth, G1–G5 = repetition groups, HJ = hurdle jump, JH = jump height, MCV = mean concentric velocity, PCP = peak concentric power, PCV = peak concentric velocity, TTPCP = time to peak concentric power, TTPCV = time to peak concentric velocity, * = significantly different ($p \leq 0.05$) than G1, † = significantly different ($p \leq 0.05$) than BJ.*

Table 12. Mean ± standard deviation and post hoc pairwise comparison of force platform data across 30 box and hurdle jumps.

		G1	**G2**	**G3**	**G4**	**G5**	**Total**
PF-v (N)	**BJ**	2001.6 ± 293.5	2068.0 ± 320.7	2089.3 ± 335.6	2115.6 ± 365.6	2092.1 ± 333.4	2073.3 ± 331.8
	HJ	2031.9 ± 284.1	2057.8 ± 271.9	2079.2 ± 310.2	2074.8 ± 308.8	2070.7 ± 315.4	2062.9 ± 298.0
	Total	2016.8 ± 288.6	2062.9 ± 296.7 *	2084.3 ± 322.5 *	2095.2 ± 338.3 *	2081.4 ± 324.0	–
RFD (N·s^{-1})	**BJ**	5373.5 ± 2498.7	6544.0 ± 2687.5	6923.2 ± 2841.5	7043.5 ± 3205.4	7050.6 ± 2763.5	6587.0 ± 2872.5
	HJ	5375.6 ± 1908.9	6284.2 ± 1802.7	6604.0 ± 2150.0	6727.9 ± 2215.8	6752.6 ± 2555.1	6348.9 ± 2196.7
	Total	5374.6 ± 2218.8	6414.1 ± 2293.0 *	6763.6 ± 2519.4 *	6885.7 ± 2754.1 *	6901.6 ± 2660.0 *	–
IF-v (N)	**BJ**	2206.6 ± 774.9	2105.9 ± 676.5	2191.6 ± 646.4	2146.4 ± 688.7	2200.3 ± 675.6	2170.1 ± 692.5
	HJ	4114.4 ± 1079.0	4017.3 ± 907.5	4115.1 ± 1007.2	4112.5 ± 835.7	4288.9 ± 1050.1	4129.6 ± 980.8 †
	Total	3160.5 ± 1338.8	3061.6 ± 1247.0	3153.3 ± 1281.4	3129.4 ± 1246.7	3244.6 ± 1368.0	–

*BJ = box jump, G1–G5 = repetition groups, IF-v = peak vertical landing force, HJ = hurdle jump, PF-v = peak vertical take-off force, RFD = average take-off rate of force development, * = significantly different (p ≤ 0.05) than G1, † = significantly different (p ≤ 0.05) than BJ.*

Table 13. ANOVA and effect size results for dependent variables across 30 box and hurdle jumps.

	Condition Effect		**Exercise Volume Effect**		**Condition × Exercise Volume Interaction Effect**	
	p-value	**f [95% CI]**	**p-value**	**f [95% CI]**	**p-value**	**f [95% CI]**
CMD	0.116	0.38 [0.00 to 0.84]	0.015	0.51 [0.21 to 0.72]	0.877	0.08 [0.00 to 0.08]
PF-v	0.650	0.11 [0.00 to 0.55]	0.023	0.47 [0.16 to 0.68]	0.126	0.33 [0.00 to 0.51]
RFD	0.434	0.18 [0.00 to 0.63]	< 0.001	0.99 [0.69 to 1.24]	0.708	0.15 [0.00 to 0.27]
MCV	0.030	0.54 [0.00 to 1.01]	< 0.001	1.00 [0.70 to 1.26]	0.504	0.21 [0.00 to 0.36]
PCV	0.023	0.57 [0.04 to 1.04]	< 0.001	0.79 [0.49 to 1.02]	0.626	0.17 [0.00 to 0.30]
TTPCV	0.420	0.19 [0.00 to 0.64]	0.788	0.13 [0.00 to 0.24]	0.582	0.19 [0.00 to 0.34]
PCP	0.151	0.34 [0.00 to 0.80]	< 0.001	0.72 [0.43 to 0.95]	0.785	0.13 [0.00 to 0.23]
TTPCP	0.849	0.04 [0.00 to 0.44]	0.831	0.14 [0.00 to 0.26]	0.163	0.31 [0.00 to 0.49]
JH	0.015	0.61 [0.11 to 1.10]	0.116	0.36 [0.00 to 0.54]	0.798	0.11 [0.00 to 0.18]
IF-v	< 0.001	3.67 [2.42 to 4.91]	0.245	0.28 [0.00 to 0.45]	0.666	0.16 [0.00 to 0.29]
RPE	0.867	0.04 [0.00 to 0.27]	–	–	–	–

CMD = countermovement depth, IF-v = peak vertical landing force, JH = jump height, MCV = mean concentric velocity, PCP = peak concentric power, PCV = peak concentric velocity, PF-v = peak vertical take-off force, RFD = average take-off rate of force development, TTPCP = time to peak concentric power, TTPCV = time to peak concentric velocity, RPE = rating of perceived exertion, p-value = probability value resulting from ANOVA test, f [95% CI] = Cohen's f effect size for ANOVA test with two-sided 95% confidence interval.

7.3 Inter-repetition rest duration

7.3.1 Baseline levels

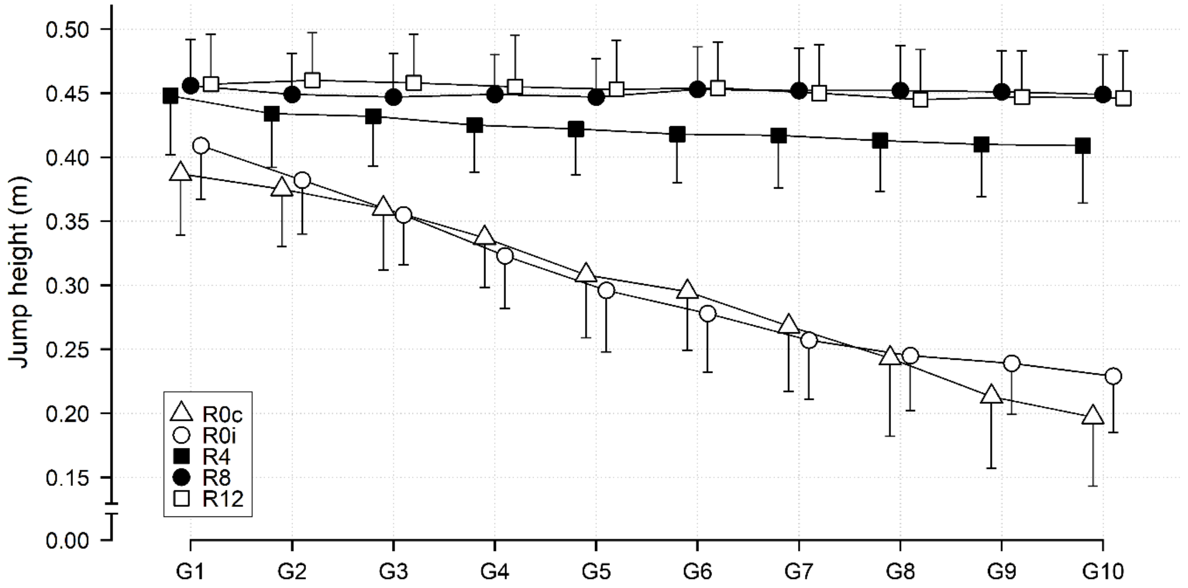
No significant differences between experimental protocols were observed for muscle soreness ($F_{4,52} = 0.609$, $p = 0.658$, $\eta_p^2 = 0.018$), heart rate ($F_{4,52} = 0.137$, $p = 0.968$, $\eta_p^2 = 0.004$), blood lactate concentration ($F_{4,52} = 0.842$, $p = 0.505$, $\eta_p^2 = 0.048$), TMG-Dm ($F_{2.07,26.92} = 0.81$, $p = 0.459$, GGe = 0.518, $\eta_p^2 = 0.011$), and TMG-Tc ($F_{4,52} = 1.583$, $p = 0.193$, $\eta_p^2 = 0.015$) at baseline. Results of ANOVA suggested that participants' body weight differed significantly between experimental protocols ($F_{4,52} = 2.961$, $p = 0.028$, $\eta_p^2 < 0.001$), however, post hoc analysis did not confirm this (all comparisons $p > 0.05$). On the other hand, heart rate differed significantly between protocols immediately preceding the first jump ($F_{4,52} = 6.356$, $p < 0.001$, $\eta_p^2 = 0.123$). Specifically, there was significant moderate to large elevation of heart rate in R0c and R0i compared to R4 ($p < 0.01$, $g \geq 0.77$ [0.35 to 1.22]) and in R0i compared to R8 ($p < 0.05$, $g = 0.63$ [0.25 to 1.02]). Moderate but non-significant elevation of heart rate was also observed in R0c compared to R8 and R12 as well as in R0i compared to R12 ($p > 0.05$, $g \geq 0.57$ [-0.02 to 1.16]).

7.3.2 Displacement

Jump height was significantly strongly affected by protocol ($F_{4,48} = 137.754$, $p < 0.001$, $\eta_p^2 = 0.749$), exercise volume ($F_{1.31,15.75} = 61.795$, $p < 0.001$, GGe = 0.146, $\eta_p^2 = 0.312$), and protocol × exercise volume interaction ($F_{36,432} = 47.85$, $p < 0.001$, $\eta_p^2 = 0.323$). Jump height during R0c and R0i protocols were significantly lower than the rest of the protocols from G1 and G2 onwards, respectively ($g \geq 1.17$ [0.83 to 1.52]), but with no significant difference in jump height between R0c and R0i at any point in time (g from 0.03 [-0.47 to 0.54] to 0.60 [0.10 to 1.10]). Jump height during R0i decreased significantly below G1 as soon as at G2 ($g = 0.62$ [0.43 to 0.80]); on the other hand, jump height during R0c fell significantly below G1 first at G5 ($g = 1.54$ [0.79 to 2.29]). Three different phases could be identified by looking at the R0c and R0i curves in Figure 19. From G1 to G4, there was a slightly steeper decrease of jump height in R0i compared to R0c ($g = 1.96$ [0.98 to 2.94] and 1.06 [0.45 to 1.68], respectively). Followed by similar jump height slopes from G4 to G7 in R0i and R0c ($g = 1.43$ [0.90 to 1.96] and 1.34 [0.89 to 1.79], respectively). Ending by flattened R0i curve and continuous steady decrease for R0c past G7 ($g = 0.58$ [0.28 to 0.89] 1.28 [0.90 to 1.66], respectively). Furthermore, there was no significant jump height decrease in R4, R8, and R12 protocols at any time point during the intervention. Post hoc analysis of protocol main effect showed jump heights to be significantly lower for R4 compared to R8 and R12 ($g = 0.72$ [0.57 to 0.88] and

0.75 [0.58 to 0.92], respectively), and non-significant trivial difference between R8 and R12 (g = 0.06 [-0.05 to 0.16]). Mean ± standard deviation values for jump height are presented in Figure 17.

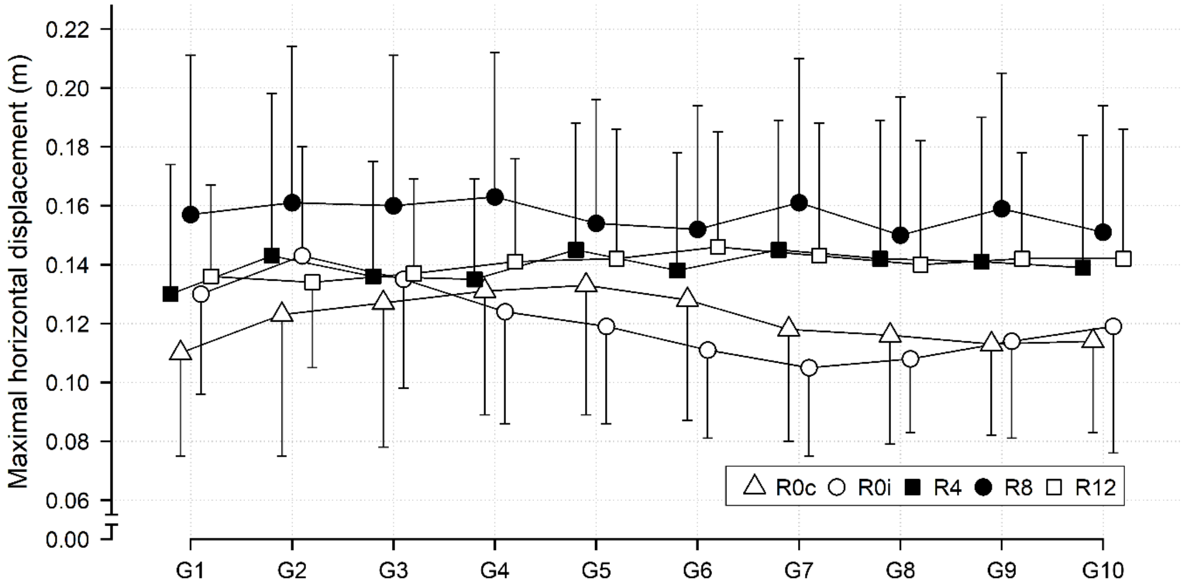
Figure 17. Mean ± SD of jump height across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

Maximal horizontal displacement showed non-significant trivial effect of exercise volume ($F_{2.14, 25.65} = 0.585$, $p = 0.575$, GGe = 0.238, $\eta_p^2 = 0.004$), significant moderate effect of protocol ($F_{4, 48} = 5.733$, $p < 0.001$, $\eta_p^2 = 0.085$), and significant small effect of protocol × exercise volume interaction ($F_{36, 432} = 1.796$, $p < 0.01$, $\eta_p^2 = 0.022$). Post hoc analysis of protocol's main effect showed significantly greater horizontal displacement for R8 compared to all other protocols (g from 0.37 [0.24 to 0.52] to 0.86 [0.65 to 1.06]). Furthermore, R4 and R12 resulted in significantly greater horizontal displacement compared to R0c and R0i (g from 0.44 [0.26 to 0.61] to 0.53 [0.33 to 0.74]). Post hoc analysis of protocol × exercise volume interaction showed no significant differences. Mean ± standard deviation values for maximal horizontal displacement are presented in Figure 18.

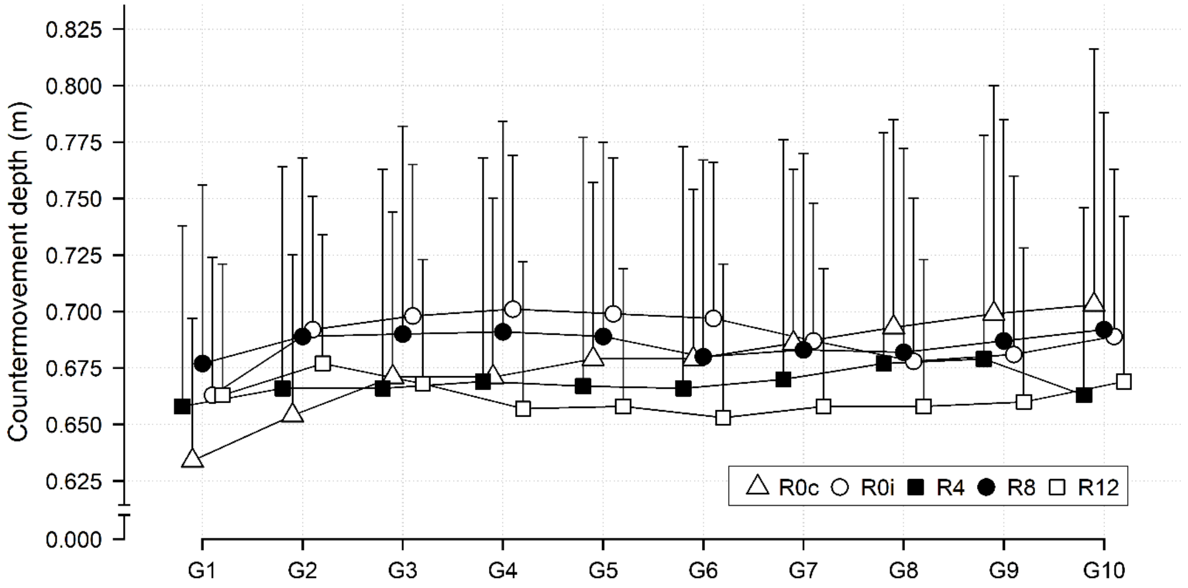
Figure 18. Mean ± SD of maximal horizontal displacement across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

There was no significant main effect of protocol ($F_{4, 48} = 0.823$, $p = 0.517$, $\eta_p^2 = 0.018$) or exercise volume ($F_{1.94, 23.23} = 1.847$, $p = 0.068$, GGe = 0.215, $\eta_p^2 = 0.007$) for countermovement depth. Small significant effect was shown for protocol × exercise volume interaction ($F_{36, 432} = 2.875$, $p < 0.001$, $\eta_p^2 = 0.018$); however, no significant differences were identified by post hoc analysis. Mean ± standard deviation values for countermovement depth are presented in Figure 19.

Figure 19. Mean ± SD of countermovement depth across 50 CMJs.

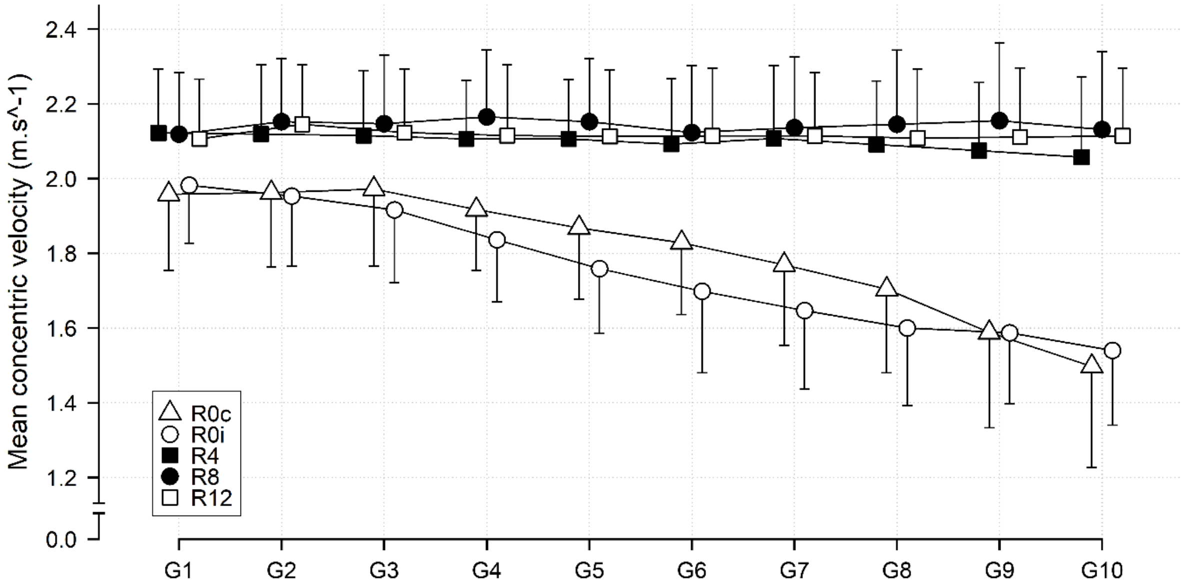


G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

7.3.3 Velocity

Mean concentric velocity resulted in significant large effect of protocol ($F_{4, 48} = 57.855$, $p < 0.001$, $\eta_p^2 = 0.443$) and significant moderate effects of exercise volume ($F_{1.26, 15.1} = 18.96$, $p < 0.001$, GGe = 0.14, $\eta_p^2 = 0.099$) as well as protocol × exercise volume interaction ($F_{36, 432} = 18.501$, $p < 0.001$, $\eta_p^2 = 0.121$). There was no significant decrease in mean concentric velocity within R4, R8, and R12 protocols throughout the intervention and there was no significant difference between these protocols. R0i was the only protocol during which, mean concentric velocity decreased significantly compared to G1 value, first at G9 (g = 2.15 [0.89 to 3.40]). Interestingly, this was in R0i preceded by significantly decreased mean concentric velocity at G8 compared to G2 (g = 1.68 [0.82 to 2.56]). Decrease of mean concentric velocity in R0c did not reach statistical significance in spite of the large effect between G1 and G10 repetition groups (g = 1.81 [0.63 to 2.98]). Mean ± standard deviation values for mean concentric velocity are presented in Figure 20.

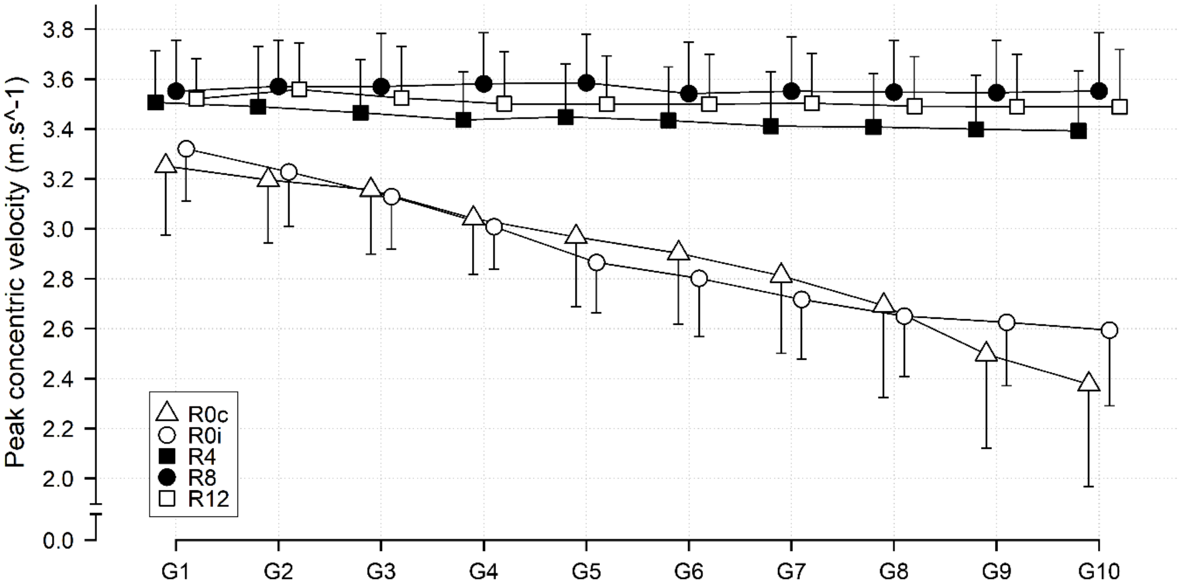
Figure 20. Mean ± SD of mean concentric velocity across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

There were significant large effects of protocol ($F_{4, 48} = 98.458$, $p < 0.001$, $\eta_p^2 = 0.62$), exercise volume ($F_{1.38, 16.61} = 38.169$, $p < 0.001$, GGe = 0.154, $\eta_p^2 = 0.186$), and protocol × exercise volume interaction ($F_{36, 432} = 27.345$, $p < 0.001$, $\eta_p^2 = 0.205$) for peak concentric velocity. Post hoc analysis indicated that there was no significant difference between any two values within or between R4, R8, and R12 protocols. Similarly, there was no significant difference between R0c and R0i protocols at any repetition group. Decrease of peak concentric velocity below G1 reached statistical significance at G3 for R0i (g = 0.85 [0.53 to 1.17]) and at G6 for R0c (g = 1.17 [0.66 to 1.68]). The effect of exercise volume resembled jump height – initial faster decrease of peak concentric velocity from G1 to G3 in R0i compared to R0c (g = 0.85 [0.53 to 1.17] and 0.33 [0.11 to 0.55], respectively), followed by comparable rate of decrease from G3 to G8 between R0i and R0c (g = 1.97 [1.00 to 2.95] and 1.31 [0.69 to 1.93], respectively), beyond which decrease of peak concentric velocity plateaued for R0i (g = 0.18 [-0.12 to 0.48]) but accelerated for R0c (g = 0.75 [0.47 to 1.03]). Mean ± standard deviation values for peak concentric velocity are presented in Figure 21.

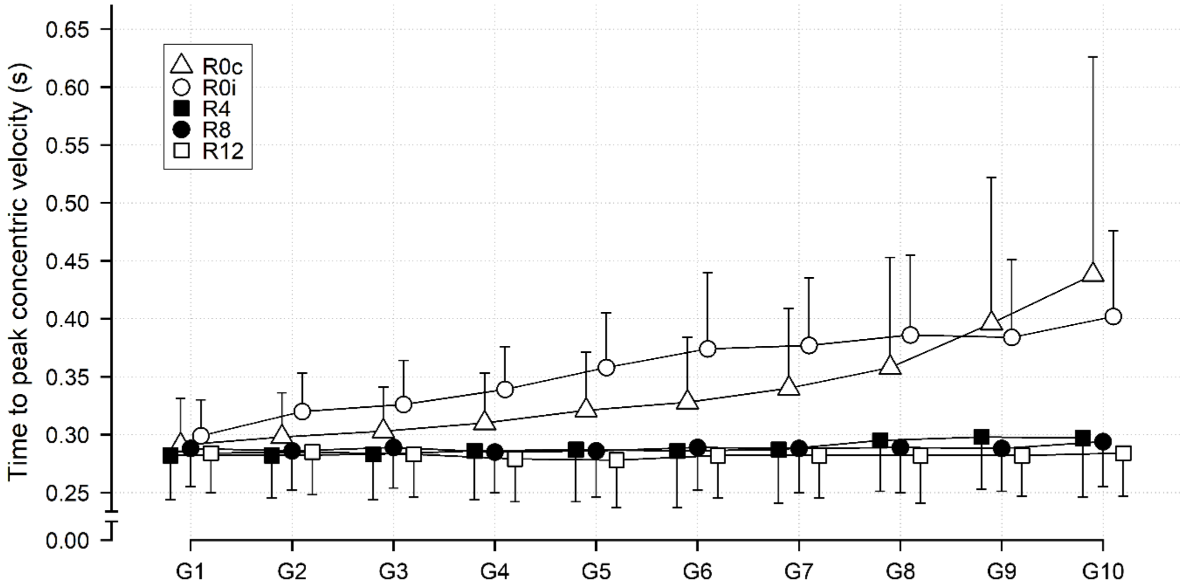
Figure 21. Mean ± SD of peak concentric velocity across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

Significant strong effect of protocol ($F_{2.25, 27.05}$ = 17.211, p < 0.001, GGe = 0.564, η_p^2 = 0.251) and significant moderate effects of exercise volume ($F_{1.36, 16.34}$ = 15.598, p < 0.001, GGe = 0.151, η_p^2 = 0.074) as well as protocol × exercise volume interaction ($F_{36, 432}$ = 8.507, p < 0.001, η_p^2 = 0.088) were seen for time to peak concentric velocity. Only R0i increased significantly above its G1 value during the intervention; however, only at G5 (g = 1.26 [0.74 to 1.77]), G7 (g = 1.34 [0.78 to 1.90]), and G10 (g = 1.43 [0.76 to 2.10]). Significant between protocol differences of time to peak concentric velocity within individual repetition groups of the intervention were seen only for R0i which was greater than R4 at G5 and G7 (both g ≥ 1.45 [0.77 to 2.14]), greater than R8 from G3 to G10 except G6 (all g ≥ 0.93 [0.65 to 1.24]), and greater than R12 at G4, G5, G7, and G10 (g ≥ 1.50 [0.86 to 2.15]). There were no significant differences of protocol × exercise volume interaction between R0c and the rest of the experimental protocols, most likely due to high inter-individual variability in R0c. Furthermore, there was no significant difference between R4, R8, and R12 at any repetition group. Mean ± standard deviation values for time to peak concentric velocity are presented in Figure 22.

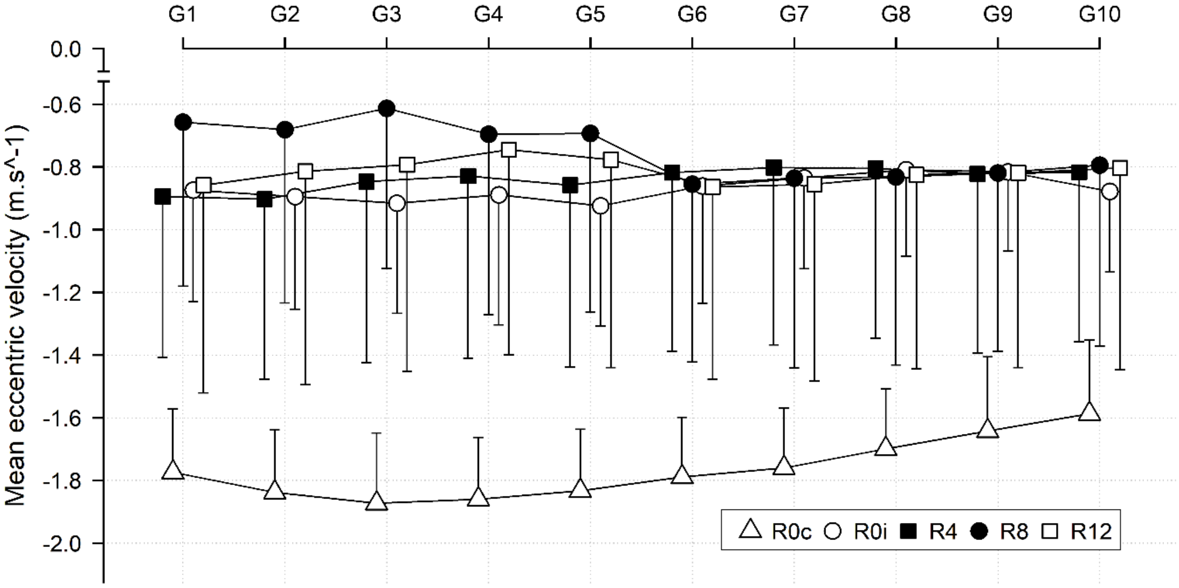
Figure 22. Mean ± SD of time to peak concentric velocity across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

Mean eccentric velocity was not significantly affected by exercise volume ($F_{3.06, 36.74}$ = 1.204, p = 0.322, GGe = 0.34, η_p^2 = 0.001), but protocol ($F_{1.55, 18.59}$ = 24.346, p < 0.001, GGe = 0.387, η_p^2 = 0.379) and protocol × exercise volume interaction ($F_{36, 432}$ = 2.273, p < 0.001, η_p^2 = 0.015) resulted in significant large and small effects, respectively. Neither experimental protocol showed any significant changes throughout the intervention. Additionally, there were no significant differences between intermittent experimental protocols (R0i, R4, R8, and R12) at any single repetition group during the intervention. However, R0c was significantly faster than R0i at every repetition group (g ≥ 2.71 [1.02 to 4.41]), faster than R4 at G1-G8 except G2 and G6 (g ≥ 2.03 [0.82 to 3.23]), faster than R8 at G1-G6 (g ≥ 1.97 [0.86 to 3.08]), and faster than R12 at G3-G5 (g ≥ 1.91 [0.83 to 3.00]). Mean ± standard deviation values for mean eccentric velocity are presented in Figure 23.

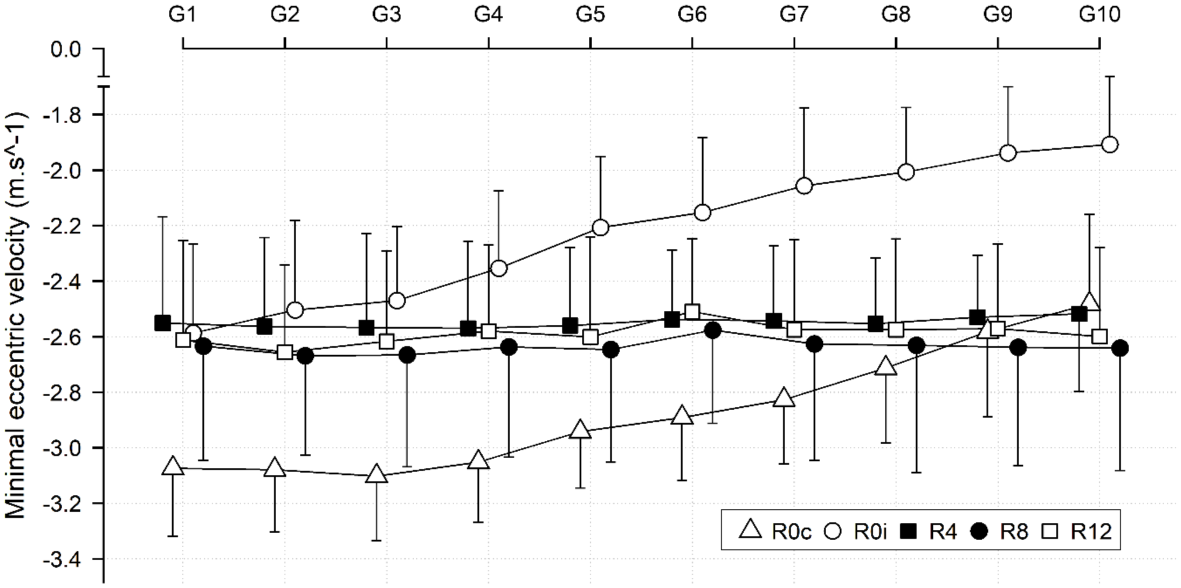
Figure 23. Mean ± SD of mean eccentric velocity across 50 CMJs.



G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

There was a significant large effect of protocol ($F_{4, 48} = 28.357$, $p < 0.001$, $\eta_p^2 = 0.404$) as well as significant moderate effects of exercise volume ($F_{2.14, 25.67} = 16.683$, $p < 0.001$, GGe = 0.238, $\eta_p^2 = 0.099$) and protocol × exercise volume interaction ($F_{36, 432} = 11.935$, $p < 0.001$, $\eta_p^2 = 0.126$) for minimal eccentric velocity. Post hoc analysis showed no significant differences compared to G1 within individual experimental protocols throughout the intervention. Although, there was non-significant large effect for slowing minimal eccentric velocity in R0c and R0i protocols from G1 to G10 (g = 1.96 [0.49 to 3.43] and 2.26 [0.62 to 3.89], respectively). Furthermore, R0c protocol was significantly faster than R0i protocol at every repetition group ($g \geq 1.58$ [0.81 to 2.35]) and R4 protocol was significantly faster than R0i at G8 and G9 ($g \geq 2.19$ [1.05 to 3.33]). Mean ± standard deviation values for minimal eccentric velocity are presented in Figure 24.

Figure 24. Mean ± SD of minimal eccentric velocity across 50 CMJs.



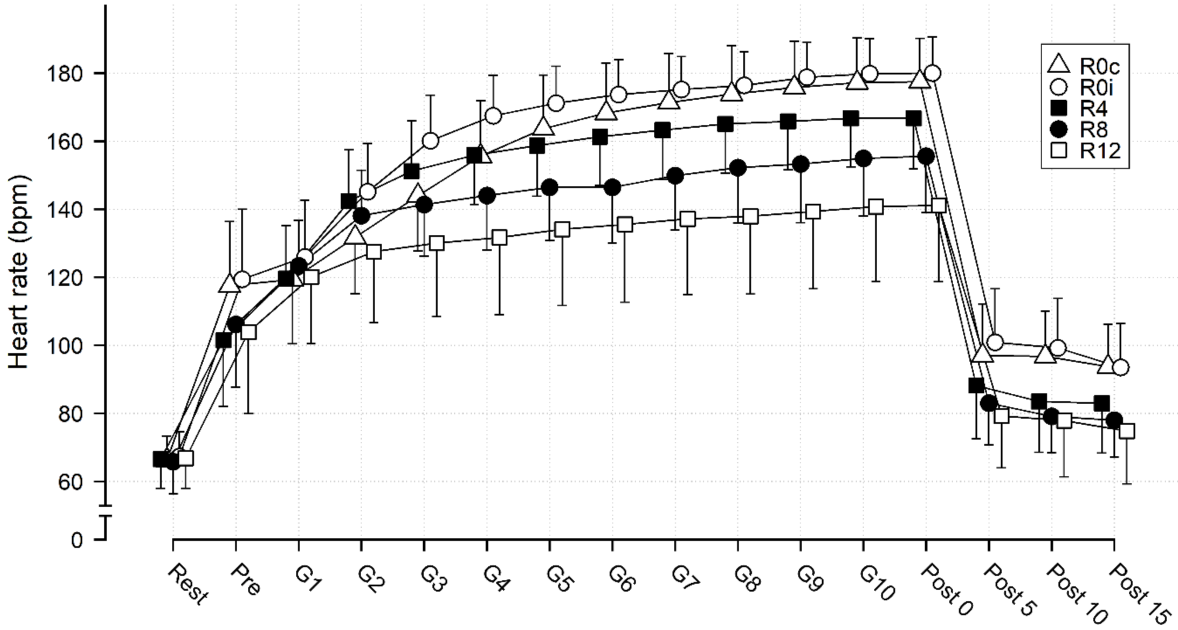
G1–G10 = repetition groups, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

7.3.4 Heart rate

There were significant strong effects of protocol ($F_{2.33, 30.27} = 32.237$, $p < 0.001$, GGe = 0.582, $\eta_p^2 = 0.286$) and time ($F_{15, 195} = 755.89$, $p < 0.001$, $\eta_p^2 = 0.823$) and significant moderate effect of protocol × time interaction ($F_{60, 780} = 17.792$, $p < 0.001$, $\eta_p^2 = 0.115$) for heart rate. Post-hoc analysis showed that heart rate in all experimental protocols increased significantly above their respective PRE value. This happened already at G1 during R4 (g = 0.84 [0.62 to 1.06]), R8 (g = 0.42 [0.34 to 0.50]), and R12 (g = 0.54 [0.41 to 0.68]) and at G2 during R0c (g = 0.68 [0.53 to 0.82]) and R0i (g = 1.26 [0.75 to 1.78]). Heart rate subsequently reached its peak and did not further significantly increase from G6 during R4 and R12 (161.3 ± 14.4 and 135.5 ± 22.8 bpm, respectively), G7 during R0i and R8 (175.2 ± 9.7 and 149.9 ± 16.0 bpm, respectively), and G8 during R0c (173.8 ± 14.2 bpm). These peak heart rate values differed significantly between protocols – R12 was lower than R4 (g = 1.01 [0.42 to 1.60]), R0i (g = 2.07 [0.72 to 3.43]), and R0c (g = 1.82 [0.62 to 3.03]); also, R8 was lower than R0i (g = 1.64 [0.97 to 2.31]). During the post-intervention recovery period, heart rate returned to resting level fastest after R12 protocol, already at 5-minutes post-intervention. Heart rate after R8 and R4 protocols returned to resting levels at 10-minutes post-intervention, but heart rate remained significantly elevated above resting levels even 15 minutes after R0c and R0i protocols (g =

2.41 [1.36 to 3.46] and 2.10 [1.30 to 2.89], respectively). Mean ± standard deviation values for heart rate are presented in Figure 25.

Figure 25. Mean ± SD of heart rate across 50 CMJs.

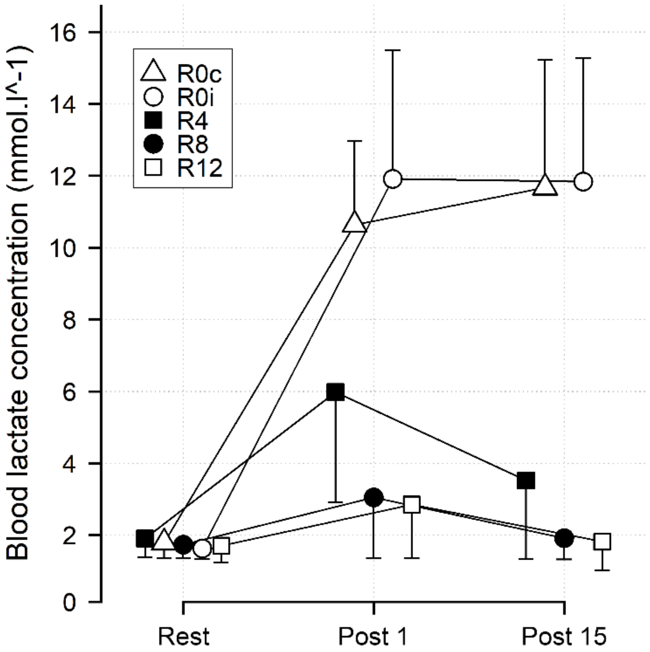


G1–G10 = repetition groups, Post 0–15 = measurement 0–15 min. after the last jump, Pre = measurement 1 second before the first jump, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest, Rest = resting value.

7.3.5 Blood lactate concentration

Analysis of blood lactate concentrations showed significant large effects for protocol ($F_{4,52}$ = 123.898, $p < 0.001$, $\eta_p^2 = 0.661$), time ($F_{2,26}$ = 106.205, $p < 0.001$, $\eta_p^2 = 0.565$) and protocol × time interaction ($F_{3.01,\ 39.16}$ = 39.16, $p < 0.001$, GGe = 0.377, $\eta_p^2 = 0.512$). Blood lactate concentrations after completing the R0c and R0i protocols were significantly elevated compared to resting levels at 1- (g = 5.09 [2.25 to 7.93] and 4.00 [1.68 to 6.31], respectively) and 15-minutes (g = 3.91 [1.59 to 6.23] and 4.05 [1.75 to 6.34], respectively). Additionally, blood lactate concentration was significantly elevated above resting levels at 1 minute after completing R4 protocol (g = 1.06 [0.57 to 1.54]), but then returned to baseline level at 15 minutes after the protocol. No significant changes in blood lactate concentration compared to resting values were observed after R8 and R12 protocols. Mean ± standard deviation values for blood lactate concentration are presented in Figure 26.

Figure 26. Mean ± SD of blood lactate concentration across 50 CMJs.



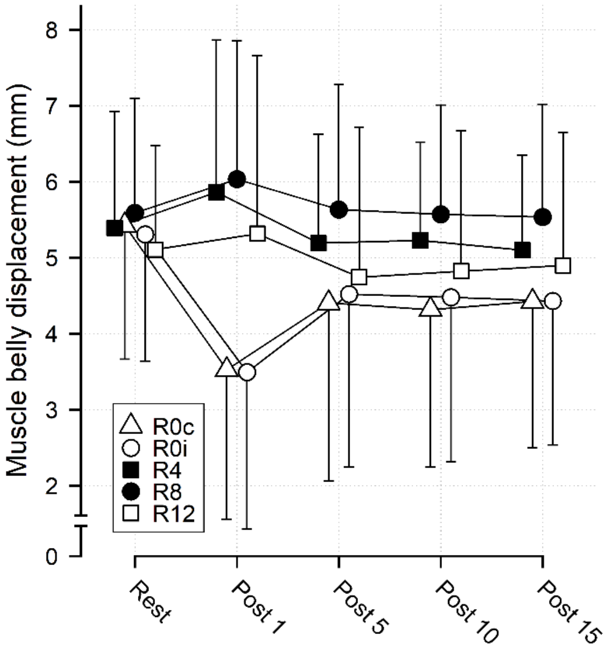
Post 1 = measurement 1 min. after the last jump, Post 15 = measurement 15 min. after the last jump, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest, Rest = resting value.

7.3.6 Tensiomyography

TMG-Dm showed small effect of time ($F_{2.36, 28.27} = 4.559$, $p = 0.015$, GGe = 0.589, $\eta_p^2 = 0.012$), moderate effect of protocol ($F_{2.29, 27.45} = 4.06$, $p = 0.024$, GGe = 0.572, $\eta_p^2 = 0.066$), and small effect of protocol × time interaction ($F_{16, 192} = 5.035$, $p < 0.001$, $\eta_p^2 = 0.042$), all of which were statistically significant. The most notable results of post-hoc analysis were non-significant large reductions of TMG-Dm at 1 minute after R0c (g = 0.96 [0.38 to 1.53]) and R0i (g = 0.90 [0.33 to 1.46]). In contrast, R8 resulted in a non-significant small increase of TMG-Dm 1 minute after the protocol (g = 0.25 [0.15 to 0.64]). Mean ± standard deviation values for TMG-Dm are presented in Figure 27.

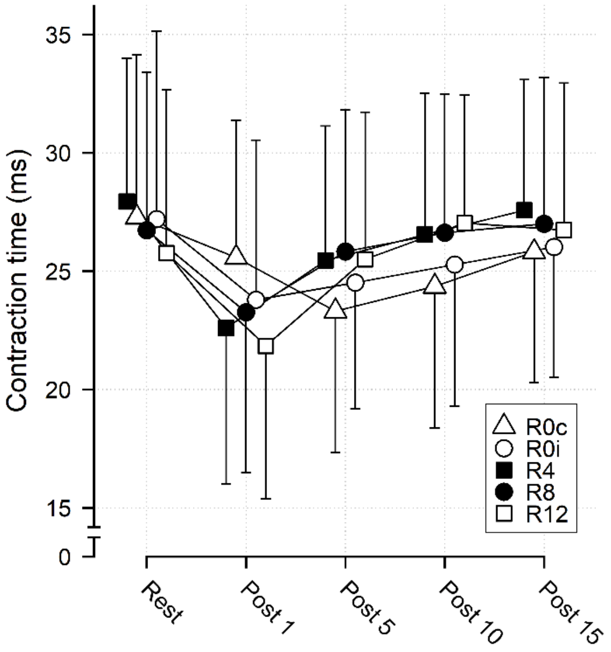
There were significant small effects of time ($F_{2.3, 27.61} = 18.808$, $p < 0.001$, GGe = 0.575, $\eta_p^2 = 0.036$) and protocol × time interaction ($F_{16, 192} = 5.234$, $p < 0.001$, $\eta_p^2 = 0.026$) for TMG-Tc and non-significant trivial effect of protocol ($F_{4, 48} = 0.438$, $p = 0.78$, $\eta_p^2 = 0.003$). TMG-Tc was significantly reduced 1 minute after completing R4 (g = 0.77 [0.58 to 0.95]) and R8 (g = 0.54 [0.34 to 0.75]) protocols compared to pre-intervention levels and recovered before 5th minute post-intervention. Also, R0i and R12 protocols resulted in lowest mean TMG-Tc at 1-minute post-intervention (g = 0.51 [0.03 to 1.05] and 0.67 [0.13 to 1.21], respectively), but neither did reach significance during the recovery period. TMG-Tc after R0c was significantly decreased only at 5-minute mark (g = 0.55 [0.34 to 0.76]) and recovered by 10th minute post-intervention. Mean ± standard deviation values for TMG-Tc are presented in Figure 28.

Figure 27. Mean ± SD of TMG-Dm across 50 CMJs.



Post 1–15 = measurement 1–15 min. after the last jump, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest, Rest = resting value.

Figure 28. Mean ± SD of TMG-Tc across 50 CMJs.

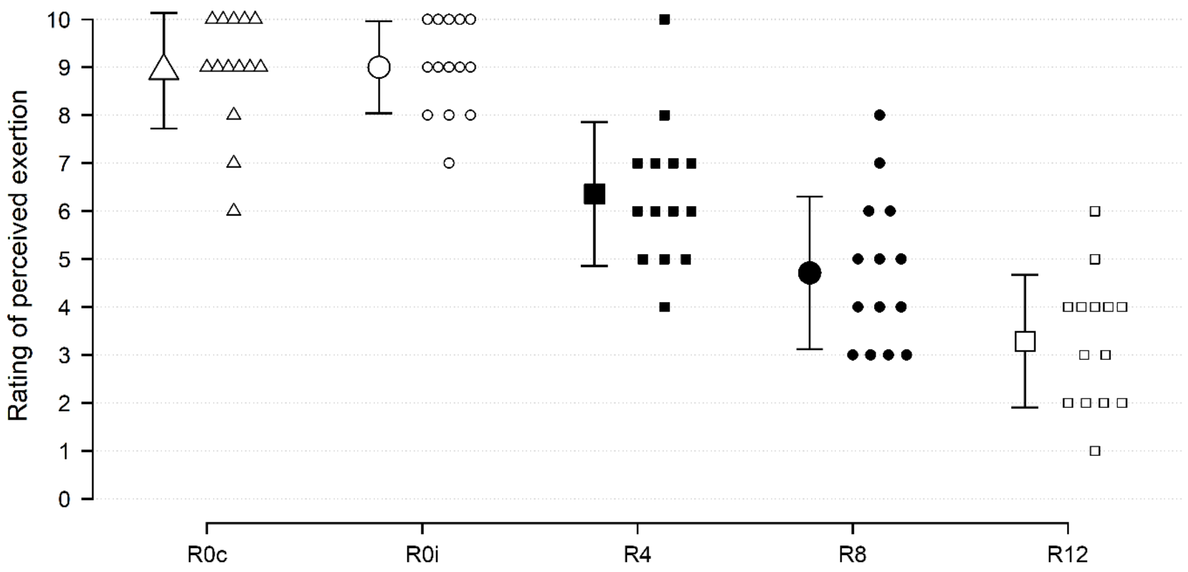


Post 1–15 = measurement 1–15 min. after the last jump, R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest, Rest = resting value.

7.3.7 Rating of perceived exertion

Significant large effect was seen for RPE between the experimental protocols ($F_{4,52}$ = 84.537, $p < 0.001$, $\eta_p^2 = 0.753$). Post hoc analysis showed significant large effects ($p < 0.05$, $g \geq 1.00$ [0.39 to 1.61]) for decreased RPE values as a result of increasing rest durations. No significant differences were seen between R0c and R0i ($g = 0.06$ [-0.27 to 0.39]) and R8 compared to R12 ($g = 0.90$ [0.22 to 1.58]). Mean ± standard deviation values for RPE are presented in Figure 29.

Figure 29. Mean ± SD of RPE immediately after 50 CMJs.



R0c = no inter-repetition rest continuously, R0i = no inter-repetition rest intermittently, R4 = 4 seconds inter-repetition rest, R8 = 8 seconds inter-repetition rest, R12 = 12 seconds inter-repetition rest.

7.3.8 Experimental protocol duration

There was significant difference in the time needed to complete individual experimental protocols ($F_{1.94,25.17} = 2815.399$, $p < 0.001$, GGe = 0.484, $\eta_p^2 = 0.992$). Specifically, R0c = 1.07 ± 0.11 min, R0i = 2.21 ± 0.19 min, R4 = 4.98 ± 0.39 min, R8 = 8.30 ± 0.44 min, and R12 = 11.42 ± 0.51 min. Post hoc analysis resulted in all differences being significant (all $p < 0.001$) with very large effect sizes (all $g \geq 6.381$ [4.52 to 8.24]).

7.4 Athlete characteristics

7.4.1 First data collection

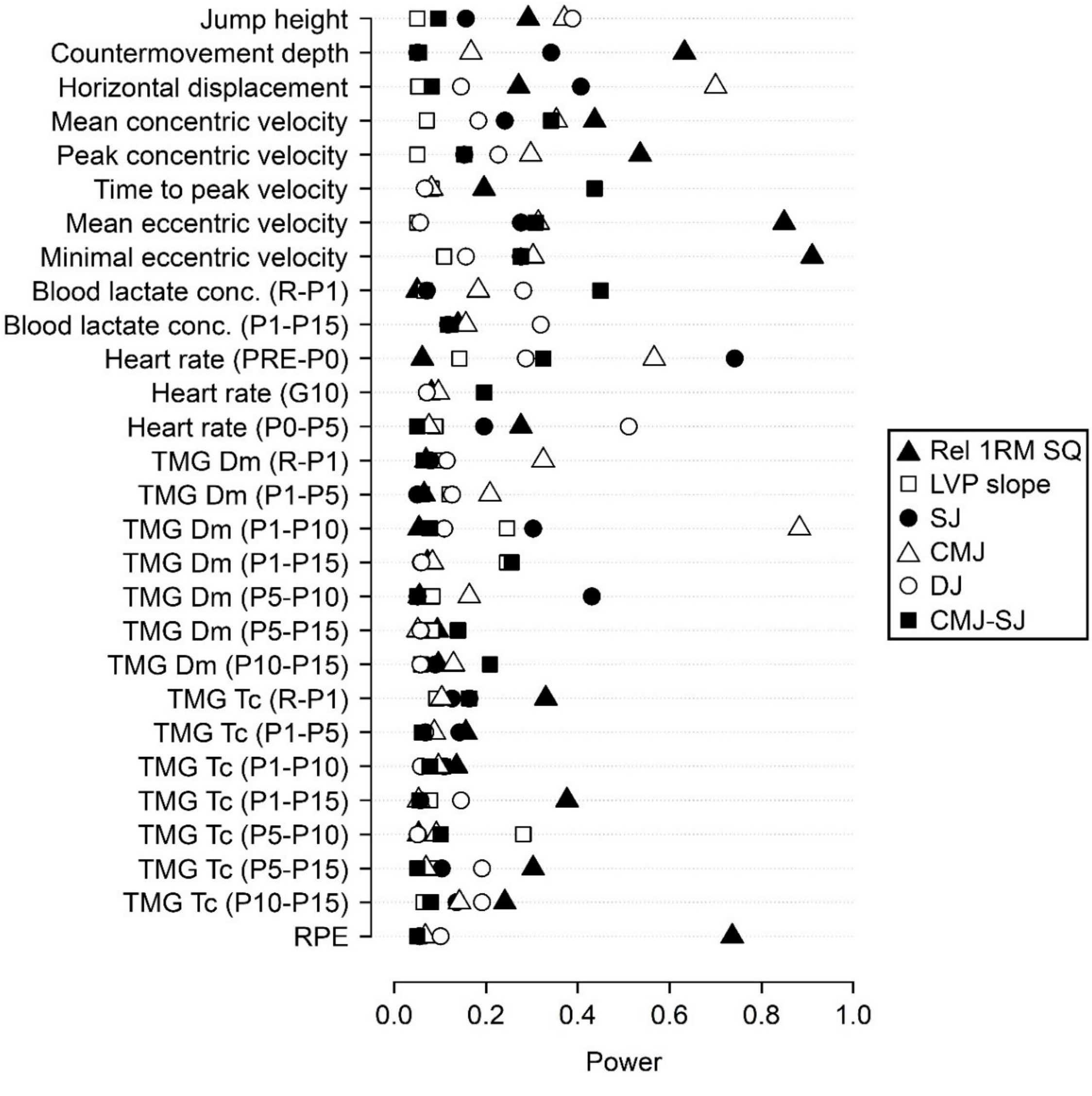
The paired samples correlation test revealed no significant relationship between body height and any of the dependent variables measured during the jump tests ($-0.42 \leq$ all r and r_s values ≤ 0.35; all p-values > 0.05). However, body weight showed a significant correlation with peak concentric power during both the BJ and HJ ($r = 0.59$, $p < 0.01$ for both jump types), and body fat percentage demonstrated a significantly correlation with PF-v and PF-r during the CMJ ($r = -0.48$ and -0.46, respectively; $p < 0.05$). Leg length exhibited significant correlations with PF-h in both BJ and HJ ($r_s = -0.54$ and -0.47, respectively; $p < 0.05$), as well as with peak concentric power in CMJ ($r_s = -0.47$, $p < 0.05$). Additionally, there was a significant correlation between upper leg length and peak concentric velocity in CMJ ($r = -0.54$, $p < 0.05$), peak concentric velocity in HJ ($r = -0.51$, $p < 0.05$), and PF-h in HJ condition ($r_s = -0.62$, $p < 0.01$). Lower leg displayed significant correlations with jump height across all three jump types ($0.46 \leq r \leq 0.52$, $p < 0.05$), which was the only relationship between anthropometric and performance variables significantly correlated across all three jump types. Furthermore, significant correlations were observed between lower leg length and peak concentric velocity, albeit only for CMJ ($r = 0.45$, $p < 0.05$), as well as with time to peak concentric velocity for HJ ($r = 0.47$, $p < 0.05$), and time to peak concentric power for HJ ($r = 0.49$, $p < 0.05$). The table presenting full results of performed correlation tests is included as Appendix 4.

7.4.2 Second data collection

The results of paired samples correlation tests revealed multiple significant relationships. Body height of participants was significantly corelated with changes in blood lactate concentration during recovery period ($r = -0.56$, $p < 0.05$) as well as with reported RPE value ($r_s = -0.55$, $p < 0.05$). Body weight was significantly correlated with RPE ($r_s = -0.63$, $p < 0.05$) and with changes in TMG-Tc value between 5th and 10th minute after the intervention ($r_s = 0.56$, $p < 0.05$). Body fat percentage correlated significantly only with amount of heart rate increase during the intervention ($r = 0.55$, $p < 0.05$). Leg length significantly correlated only with changes in countermovement depth during the intervention ($r_s = 0.58$, $p < 0.05$) and there were no significant correlations between leg length discrepancy and any of the dependent variables. Similarly, both training experience and CMJ performance showed no significant correlations to any of the dependent variables. On the other hand, SJ performance was significantly correlated with changes in mean and peak concentric velocity ($r_s = -0.72$, $p < 0.01$ and $r_s = -0.57$, $p < 0.05$, respectively), changes in mean and minimal eccentric velocity ($r_s = 0.56$, $p < 0.05$ and $r_s = 0.61$, $p < 0.05$, respectively), changes in heart rate during the intervention ($r_s = -0.80$, $p = 0.001$), and changes in TMG-Dm from 1st to 10th minute post intervention ($r_s = 0.54$, $p < 0.05$). However, drop jump only correlated significantly with changes in blood lactate concentration during recovery period ($r = 0.63$, $p < 0.05$). Absolute back squat one repetition maximum performance significantly correlated with changes in countermovement depth during the jumping intervention ($r_s = -0.58$, $p < 0.05$) and maximum back squat strength relative to individual’s bodyweight correlated significantly with changes in countermovement depth ($r_s = -0.67$, $p < 0.01$) as well as with RPE ($r_s = 0.72$, $p < 0.01$). The slope of the linear regression line for load-velocity profile was significantly correlated only with changes in heart rate during the jumping intervention (r = 0.65, p < 0.05). The tables presenting full results of performed correlation tests are included as Appendix 5 and 6.

Multiple post hoc subgroup comparisons were performed for two independent groups divided based on relative backs squat 1RM strength, slope of load-velocity profile, SJ performance, CMJ performance, DJ performance, and stretch-shortening cycle potentiation represented by difference in performance between SJ and CMJ. The results of post hoc power analysis identified only 3 instances where statistical power crossed over 0.8 threshold: change in mean and minimal eccentric velocity in subgroups divided by relative back squat 1RM strength (Power = 0.85 and 0.91, respectively) and change in TMG-Dm between 1st and 10th minute after the experimental intervention in subgroups divided by CMJ performance (Power = 0.88). Complete power analysis results are depicted in Figure 30.

Figure 30. Results of power analysis for subgroup comparisons.



All subgroups differed significantly in their respective metric, based on which they were created ($20.219 \leq F_{1,10} \leq 52.649$, all $p \leq 0.001$, $0.669 \leq \eta_p^2 \leq 0.840$). Furthermore, there were no significant differences in age, training experience, body height, body weight, or body fat percentage between subgroup pairs with the only exception being significantly different age between high and low relative back squat 1RM strength groups ($F_{1,10} = 6.204$, $p = 0.032$, $\eta_p^2 = 0.383$). Tables 14 and 15 include descriptive statistics for all included subgroups.

Table 14. Mean ± SD values of the key independent variable for all subgroups.

	Subgroups	**Mean ± SD**
Relative back squat 1RM ($kg \cdot kg^{-1}$)	Higher strength	1.768 ± 0.146 *
	Lower strength	1.376 ± 0.128
Slope of load-velocity profile ($m \cdot s^{-1} \cdot kg^{-1}$)	Higher steepness	−0.010 ± 0.001 *
	Lower steepness	−0.007 ± 0.001
Squat jump (m)	Higher jump	0.502 ± 0.017 *
	Lower jump	0.426 ± 0.019
Countermovement jump (m)	Higher jump	0.539 ± 0.019 *
	Lower jump	0.462 ± 0.020
Drop jump (m)	Higher jump	0.523 ± 0.018 *
	Lower jump	0.453 ± 0.024
Stretch-shortening cycle potentiation (m)	Higher potentiation	0.060 ± 0.016 *
	Lower potentiation	0.014 ± 0.016

** = significantly different ($p \leq 0.05$) compared to the other subgroup of the same key variable.*

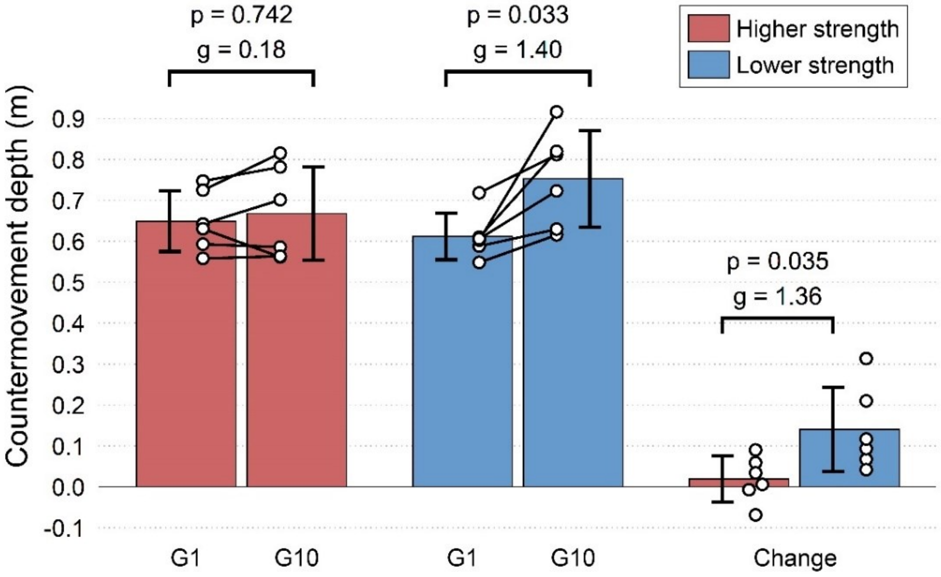
Table 15. Descriptive statistics of included subgroups.

	Subgroup	**Age (years)**	**Training Experience (years)**	**Body Height (m)**	**Body Weight (kg)**	**Body Fat (%)**
Relative back squat 1RM (kg·kg^{-1})	Higher strength	27.70 ± 3.77 *	11.67 ± 622	1.77 ± 0.06	79.04 ± 4.93	13.13 ± 5.57
	Lower strength	23.28 ± 2.16	7.83 ± 4.12	1.86 ± 0.09	88.23 ± 13.63	8.27 ±5.88
Slope of LVP (m·s^{-1}·kg^{-1})	Higher steepness	24.97 ± 3.01	8.33 ± 4.27	1.80 ± 0.05	80.88 ± 13.32	8.58 ± 5.51
	Lower steepness	25.38 ± 2.76	10.33 ± 3.45	1.84 ± 0.12	90.78 ± 7.42	11.98 ± 5.63
Squat jump (m)	Higher jump	24.24 ± 2.24	7.33 ± 3.20	1.82 ± 0.03	85.40 ± 7.42	7.80 ± 3.13
	Lower jump	26.02 ± 4.61	11.33 ± 6.44	1.83 ± 0.12	88.89 ± 13.07	13.13 ± 7.32
CMJ (m)	Higher jump	24.11 ± 2.06	7.00 ± 2.97	1.80 ± 0.03	82.03 ± 8.35	7.98 ± 3.19
	Lower jump	26.50 ± 4.51	10.83 ± 6.40	1.83 ± 0.12	87.31 ± 11.75	12.25 ± 7.58
Drop jump (m)	Higher jump	24.87 ± 2.14	8.67 ± 3.78	1.82 ± 0.05	85.27 ± 10.38	9.27 ± 3.17
	Lower jump	26.88 ± 4.66	11.50 ± 6.50	1.82 ± 0.12	84.39 ± 12.50	12.85 ± 7.34
SSC potentiation (m)	Higher potentiation	25.81 ± 2.59	10.17 ± 4.62	1.79 ± 0.09	85.94 ± 14.84	12.98 ± 6.52
	Lower potentiation	24.93 ± 4.51	8.50 ± 6.19	1.86 ± 0.08	86.18 ± 7.49	8.53 ± 4.66

*1RM = one repetition maximum, CMJ = countermovement jump, LVP = load-velocity profile, SSC = stretch-shortening cycle, * = significantly different ($p \leq 0.05$) compared to the other subgroup of the same key variable.*

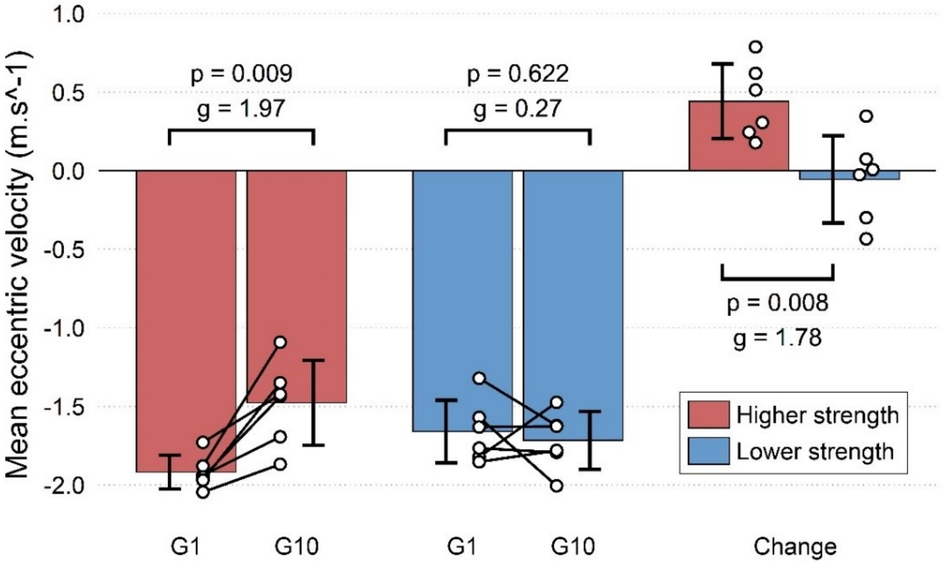
There were no significant differences in any of the dependent variables between the subgroups with different steepness of load-velocity profile slope, drop jump performance, or stretch-shortening cycle potentiation. On the other hand, the subgroup with higher relative back squat 1RM strength experienced significantly smaller increase of countermovement depth ($p < 0.05$, $g = 1.36$, Figure 31) and significantly slowed down their mean and minimal eccentric velocities ($p < 0.01$, $g < 1.78$, Figure 32 and $p < 0.01$, $g = 1.95$, Figure 33, respectively) compared to the relatively weaker subgroup.

Figure 31. Difference in countermovement depth changes throughout the continuous 50 CMJs between subgroups with higher and lower maximal strength of lower body relative to body weight.



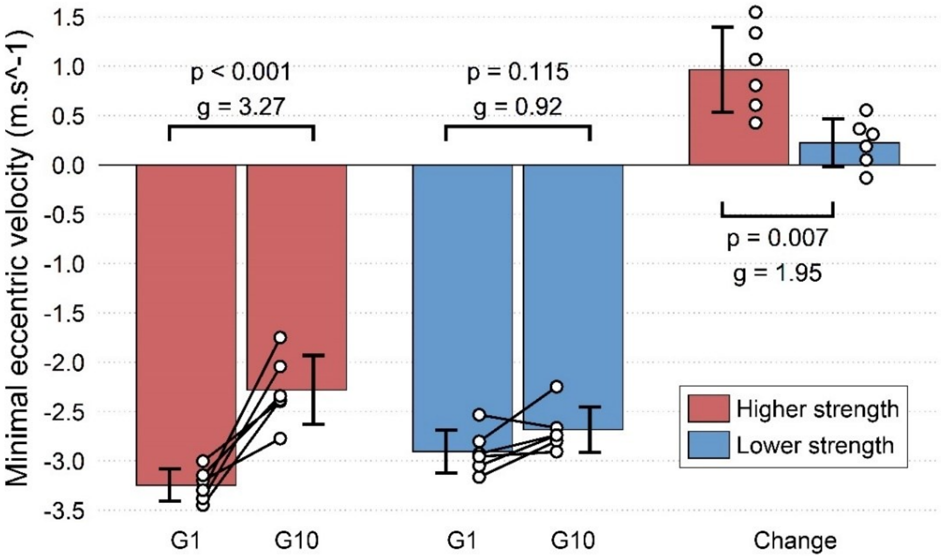
g = Hedge's g effect size, G1 = average value of initial 5 jumps, G10 = average value of final 5 jumps, p = probability value resulting from independent samples t-test.

Figure 32. Difference in mean eccentric velocity changes throughout the continuous 50 CMJs between subgroups with higher and lower maximal strength of lower body relative to body weight.



g = Hedge's g effect size, G1 = average value of initial 5 jumps, G10 = average value of final 5 jumps, p = probability value resulting from independent samples t-test.

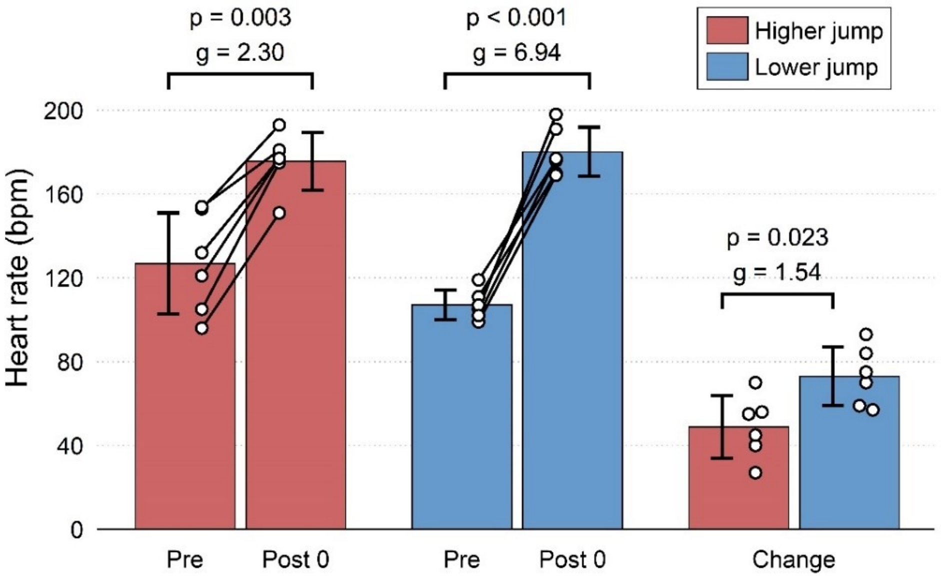
Figure 33. Difference in minimal eccentric velocity changes throughout the continuous 50 CMJs between subgroups with higher and lower maximal strength of lower body relative to body weight.



g = Hedge's g effect size, G1 = average value of initial 5 jumps, G10 = average value of final 5 jumps, p = probability value resulting from independent samples t-test.

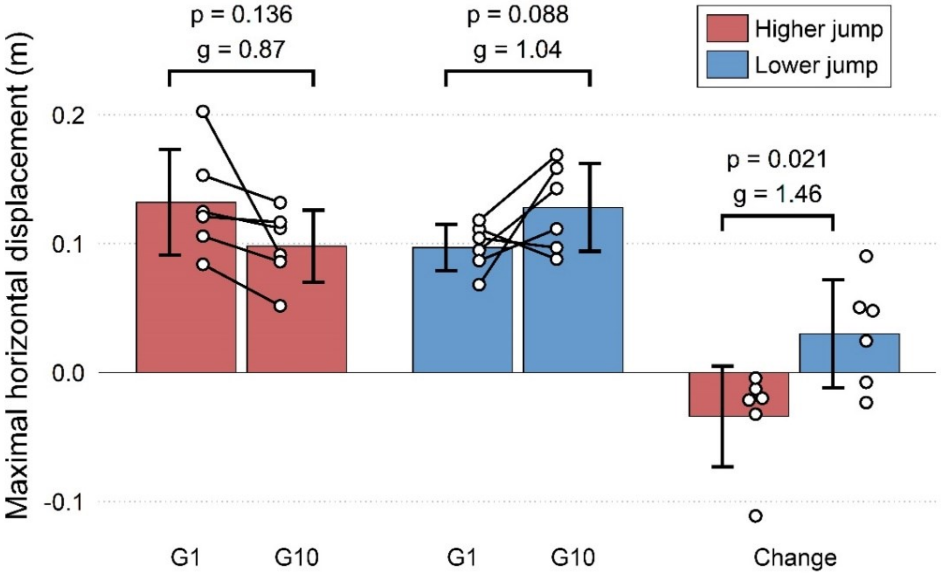
Furthermore, significantly smaller increase of heart rate during the experimental intervention was experienced by the subgroup with higher SJ compared to the lower SJ subgroup ($p < 0.05$, g = 1.54, Figure 34). Lastly, there were significant differences in changes to maximal horizontal displacement during the experimental intervention ($p < 0.05$, g = 1.46, Figure 35) as well as in changes of TMG-Dm values from 1st to 10th minute after the experimental intervention ($p < 0.01$, g = 1.87, Figure 36) between subgroups with higher and lower CMJ performance. Specifically, higher CMJ performance subgroup reduced the maximal horizontal displacement from G1 to G10 whereas lower CMJ performance subgroup experienced change of similar magnitude but in the opposite direction. Muscle belly displacement of vastus lateralis measured via tensiomyography increased more in the group of higher countermovement jumpers from the first to tenth minute following the jumping intervention; however, the difference was mainly in the value measured right after the intervention being non-significantly lower in the subgroups consisting of higher jumpers. The complete results of the subgroup comparisons are included as appendix 7 to 12.

Figure 34. Difference in heart rate changes resulting from continuous 50 CMJs between subgroups with higher and lower squat jump performance.



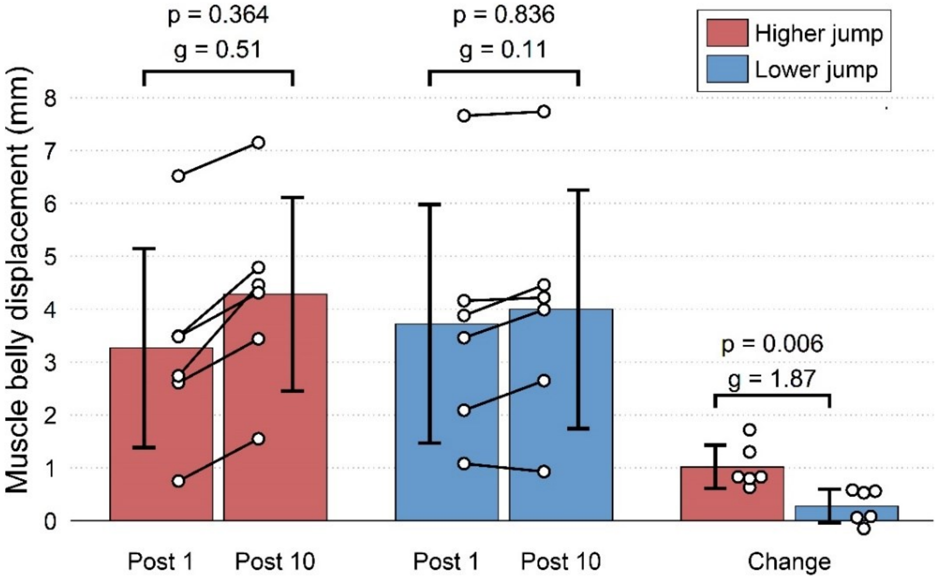
g = Hedge's g effect size, p = probability value resulting from independent samples t-test, Post 0 = measurement immediately after the last intervention jump, Pre = measurement 1 second before the initiation of the first intervention jump.

Figure 35. Difference in maximal horizontal displacement changes throughout the continuous 50 CMJs between subgroups with higher and lower countermovement jump performance.



g = Hedge's g effect size, G1 = average value of initial 5 jumps, G10 = average value of final 5 jumps, p = probability value resulting from independent samples t-test.

Figure 36. Difference in TMG-Dm changes between 1st and 10th minute following the continuous 50 CMJs between subgroups with higher and lower countermovement jump performance.



g = Hedge's g effect size, p = probability value resulting from independent samples t-test, Post 1 = measurement 1 minute after the last intervention jump, Post 10 = measurement 10 minutes after the last intervention jump.

8 Discussion

8.1 Comparison of common jumping exercises

Three commonly used jumping exercise variations – CMJ, BJ, and HJ – were used throughout this dissertation thesis. Even though these variations are similar, our data show that the requirement of overcoming an obstacle resulted in some technical adjustments and consecutive differences in propulsive performance. Contrary to our hypothesis, countermovement depth was significantly shorter in BJ and HJ compared to CMJ, in other words, participants' shoulders lowered significantly deeper during CMJ than both BJ and HJ. Unsurprisingly, PF-h was significantly larger in BJ and HJ compared to CMJ but no differences were observed in PF-v, PF-r, and RFD. Similarly, there were no significant differences between the jump types in peak and mean concentric velocities as well as total impulsion time. On the other hand, peak concentric power was significantly larger in BJ compared to CMJ and time to peak concentric power and peak concentric velocity were significantly shorter for both jumps involving obstacle compared to CMJ condition. Jump height was the only variable with significant differences between all three jump types, the CMJ being the highest and the HJ being the lowest.

As hypothesized, BJ significantly reduced IF-v and IF-r compared to those experienced during HJ and CMJ. Although the results highlight some important differences between these commonly used jump types, the differences were not as vast as initially hypothesized. One of the main findings is the similar level of PF-v and PF-r in all three jump types despite approximately fourfold differences in PF-h when jumping over or onto the obstacle. These results support the previous research showing that performing BJs to boxes of various heights resulted in non-significant trivial to small differences in peak take-off force and power, RFD, and concentric time to take-off (Koefoed et al., 2022). However, contrary to our results, this study reported that box height did not alter jump height. Although, the direct comparison to our results is difficult due to the obstacle being present in both high and low box conditions. The study also tested CMJ performance but unfortunately only the lack of relationship between maximal achievable box height and CMJ performance was reported.

The participants adopted their natural countermovement depth during all conditions to increase ecological validity. This resulted in significantly different countermovement depth between the jump types with and without obstacle. Previous research repeatedly linked countermovement depth with total impulsion time (Jidovtseff et al., 2014; Pérez-Castilla, Rojas, et al., 2021; Pérez-Castilla, Weakley, et al., 2021) which can lead to two different acute benefits when manipulated. First, greater displacement associated with deeper countermovement depth allows for greater concentric work and possibly also higher velocities to be achieved (Jidovtseff et al., 2014; Pérez-Castilla, Rojas, et al., 2021; Pérez-Castilla, Weakley, et al., 2021). This would provide sport-specific stimulus for athletic events which require a high rate of forces to be produced from deep squat positions such as weightlifting, ski jumps, sprint, swimming, sumo, etc. Second acute benefit of altering total impulsion time can be more efficient use of stretch-shortening cycle achieved via decreased countermovement depth (i.e., decreased range of motion) and therefore decreasing the total impulsion time. This change can result in greater concentric and eccentric power production (Guess et al., 2020) as well as greater eccentric work, greater concentric force, greater amortization, and lower amortization time (Barker et al., 2018). As a result of this, jump types which promote shallower countermovement depths would be more specific for athletes relying on effective stretch-shortening cycle (e.g., basketball, volleyball, high jump, gymnastics, etc.).

Contrary to the studies mentioned in the previous paragraph, our data show that present significant differences in countermovement depth did not yield significant differences in most of the key propulsive variables such as total impulsion time, peak and mean concentric velocities, PF-v, PF-r, and RFD. This discrepancy between previous research and our data might be explained by the countermovement depth being measured as vertical displacement of the dowel being held across participants' shoulders instead representing the displacement of their center of mass. Therefore, the deviations in countermovement depth presented in this thesis could be indicative of participants' keeping a more upright torso position in the presence of an obstacle being placed in front of them during the countermovement. Considering that this technical adjustment resulted in only moderate-to-strong significant differences in concentric power and times to peak concentric power and velocity, it is plausible that these three jump types may impose similar propulsive stimuli. This could justify their interchangeability in certain training contexts and allow some applications of research findings across these jump types.

As hypothesized, there was a significant large effect of jump type for IF-v and IF-r; specifically, the impact forces were significantly lower during BJ than both HJ and CMJ. This finding is in agreement with previously reported significant reduction in peak joint power absorption in BJ compared to CMJ and HJ (Van Lieshout et al., 2014). Our data show that on average the BJ caused approximately two-fold (~51 %) reduction of impact forces compared to CMJ and HJ which is quite remarkable effect. The two main factors could be considered responsible for such robust impact reduction: the instruction to perform a soft landing and a coincidental matching of research sample's mean jump height (49.5 cm) with a height of the box used during the intervention (50 cm). This raises an intriguing new research question related to training individualization: what is the effect of different box-to-CMJ-height ratios on impact forces upon landing?

Some training goals, such as improvements in landing mechanics or increasing eccentric strength and power, might require higher impact forces to be used (Iida et al., 2013); however, other situations like patellofemoral sensitivity or periods of increased training and/or competitive load might warrant lower impact forces to reduce total load (Lack et al., 2018; Sisk & Fredericson, 2019). Previous research have shown that level of patellofemoral pain was significantly positively correlated with higher magnitudes and rates of eccentric forces in patellofemoral joint upon landing in young symptomatic women (Atkins et al., 2018). Furthermore the ability to effectively absorb impact forces seems to be compromised while experiencing acute patellofemoral pain (Nunes et al., 2019), which might negatively affect injury risk. Therefore, coaches could use BJs to effectively reduce impact forces while maintaining similar levels of propulsive performance when warranted.

Our data provide a foundation for evidence-based plyometric exercise selection; however, many questions related to this topic remain unanswered. For example, previously mentioned relationship between CMJ performance and box height, but also an enhanced effect of stretch-shortening cycle during multiple continuous jumps, potentiating effect of multiple intermittent jumps, or effect of fatigue resulting from higher volume sets. Furthermore, there are some limitations associated with this experiment which should be taken into consideration when interpreting and applying our findings. First, the string of the linear position transducer was attached to one end of the dowel held by the participants across their shoulders. This could lead to a potential measurement effort in case participant's shoulders rotate or tilt during the experimental task. However, one member of the research team was responsible for monitoring the position of the dowel throughout the whole experiment to minimize the negative impact of said movements. Any repetitions with excessive dowel motions were noted and excluded from analysis. Second, on a similar note, the data measured via the linear position transducer could be negatively influenced by participant's jump technique, specifically the amount of forward lean of the trunk during the countermovement. This could be mitigated by choosing a different site for attachment of the wire, such as participant's waist. Additional benefit of this attachment site would enable participants to use arm swing and therefore to increase ecological validity. Although, this was not possible in the current experiment due to some technical constraints of the equipment used mainly during the HJ condition (i.e., the string of the linear position transducer hitting the top of the hurdle in the later part of the jump). Therefore, attachment via the dowel held across participant's shoulders was used in all conditions for consistency.

8.2 Effects of impact forces across a set of repeated jumps

Our initial hypothesis was not fully supported by the results of this experiment. In short, we hypothesized that there will be significant fatigue-related performance decline in HJ condition but no significant decline of performance in BJ condition throughout the intervention. Contrary to our hypothesis, the results show no fatigue-related performance decrease in both conditions and even improvement of multiple variables (mean and peak concentric velocity, peak concentric power, PF-v, and RFD) throughout the intervention.

In plyometric type jumps, the total eccentric loading consists of eccentric work during the countermovement which precedes take-off and eccentric work upon landing to stop the downward movement (Suchomel et al., 2019a). Therefore, the total eccentric loading in plyometric type jump exercises is heavily influenced by the magnitude of impact forces upon landing (Heise & Martin, 2001; Peng, 2011; Williams & Cavanagh, 1987; Yeow et al., 2010). This is important because eccentric fatigue, resulting from repeated intense eccentric contractions, can blunt the ability to produce dynamic force (Byrne et al., 2001; Denis et al., 2011) which is however, not limited to eccentric contractions but can also negatively affect concentric performance (Byrne et al., 2001; Nuzzo et al., 2023). Therefore, we expected that reducing the distance between the apex of the jump and the landing surface via elevated landing platform and in turn reducing the impact forces (Van Lieshout et al., 2014) might assist in preventing fatigue-related reduction of take-off performance during a set of repeated high effort jumps. However, our data present a slightly different narrative.

In our experiment, the BJ produced approximately two times lower impact forces compared to the HJ (Table 12), as expected. However, the potential positive effect of significantly reduced impact forces on the ability to maintain repeated jumping performance could not be observed, as neither condition led to any negative fatigue-related changes to take-off performance. It could be argued that the impact forces produced by the HJ, or the volume performed (30 jumps) might not be great enough to cause any observable performance detriments in our experiment. Although, this is unlikely because it had been demonstrated that as few as 10 DJs from a 60 cm height caused significant decrease in jumping performance (Miyama & Nosaka, 2007). This study even reported similar impact forces to those resulting from the HJ condition in our experiment (~4.0 to ~5.2 and ~5.3 times body weight, respectively). It seems that the different outcomes might stem from a difference in participants' training experience. Our experiment involved physically active participants with experienced in plyometric training, whereas the study by Miyama and Nosaka was performed on untrained participants. Therefore, it is very plausible that both training status as well as training history can greatly impact an individual's ability to cope with the high demands of repeated high intensity plyometric jumps. This aligns with the outcomes of a recent review of practical recommendations for implementing lower body plyometric training as a form of eccentric training (Suchomel et al., 2019b) and also with our systematic literature review of factors influencing fatiguability and recovery from lower body plyometric training in the context of prescribing rest intervals (Chapter 2).

The results of our experiment showed moderate significant effects of jump type on mean and peak concentric velocities and jump height preferring the BJ condition (Table 13). These differences could be results of non-significantly greater countermovement depth, peak concentric power, and RFD associated with the BJ compared to the HJ condition (Tables 11 and 12). However, our experiment cannot provide a definitive explanation as to why these differences between the jump types emerged, given that there were identical obstacle heights for both conditions, and neither condition resulted in a fatigue-related performance decrease.

Technical adjustments made in anticipation of different levels of impact force could provide a plausible explanation for the observed inter-condition differences. Research has demonstrated that individuals adapt their movements in anticipation of different conditions. For instance, they adjust lower body stiffness from the first step when transitioning between running surfaces with expected differences in surface hardness (Ferris et al., 1999), or they modify early RFD, concentric power output, and level of muscle activation when performing bench throws with and without knowledge of the weight being used (Hernández-Davó et al., 2015). Significantly greater concentric velocity and jump height in BJ compared to HJ in our experiment could be resulting from adjustments due to much greater impact forces experienced during the HJ or specific requirements and constraints due to the shape of the obstacles. Nonetheless, coaches should consider that even small differences in seemingly similar exercises could influence an acute jumping performance.

Our main hypothesis regarding this experiment expected significant decrease of performance in the HJ condition due to larger eccentric loading compared to the BJ. The aim of this experiment in the context of the dissertation project was to establish the importance of correcting for impact forces when examining the effect of inter-repetition rest durations on fatigue-related performance decreases in a set of repeated jumps. However, contrary to our hypothesis, following the initial jumps, the performance in both conditions significantly increased. Specifically, PF-v, RFD, mean and peak concentric velocity, peak concentric power, and countermovement depth increased in magnitude (Tables 11 and 12). The plausible explanation of these outcomes might be a potentiation effect resulting from combination of participants' training status and exercise parameters used during the intervention.

Training status and training history are some of the key factors influencing fatiguability, rate of performance loss, and recovery after exhaustive plyometric exercise (Skurvydas et al., 2002). It has been shown that individuals naïve to plyometric exercise were able to significantly improve their ability to maintain performance (i.e., jump height and maximum isometric knee extension torque) after only 1 to 3 plyometric sessions (Dias et al., 2022; Kamandulis et al., 2019; Miyama & Nosaka, 2007; Skurvydas, Kamandulis, Stanislovaitis, et al., 2010). Therefore, the protocol included in our experiment might not have been exhausting enough for the participants included in this experiment since they were already experienced in plyometric training. That being said, these results should not be extrapolated to unexperienced trainees as their response might be vastly different from the results reported in this chapter. Potentially leading to acute performance decrease and causing lowered training effect and increased injury risk (Chappell et al., 2005; Yu et al., 2020).

The observed potentiating effect could also be caused by the specific inter-repetition rest duration used in this experiment, which was probably long enough to prevent accumulation of fatigue but short enough to allow maintenance of acquired potentiation (Gouvêa et al., 2013). This is in line with data on rest redistribution showing that short but more frequent rest periods can reduce or prevent loss of jumping performance within a set measured via jump height, power output, and take-off velocity (Moreno et al., 2014). Furthermore, six continuous jumps were shown to be effective in achieving jump height, estimated power, and flight time potentiation when followed by sufficient and individualized rest duration in collegiate athletes (Cazás-Moreno et al., 2021). Our findings agree with the outcomes of the aforementioned studies. In our experiment, there was a period of approximately 2 minutes separating the start of the intervention from the end of the warm-up which was instrumental for setup of the measurement devices. However, this period of inactivity might have been long enough to inhibit positive effects of preceding warm-up and therefore explain the suboptimal performance from the early stages of the intervention. The factors discussed above then probably allowed participants to regain the lost potentiation and maintain it throughout the intervention.

This experiment aimed to evaluate the effects of high-effort repeated jumps with different magnitudes of impact forces upon landing on fatigue-related changes in take-off performance and to provide insights for the design and interpretation of the following experiment examining the effect of inter-repetition rest duration in repeated jumps. However, the results did not show this effect which might be related to several limitations of this experiment. First, the magnitude of impact forces might have been too low to lead to fatigue accumulation and in turn cause significant decrease of take-off performance. Although previous research suggests that even in case of including higher obstacle (Koefoed et al., 2022) or choosing more intense exercise (e.g., DJ) (Miyama & Nosaka, 2007) the impact forces would likely remain similar. Second, the exercise volume performed in this experiment was lower than current recommendations for standalone plyometric protocols (>50 and >40 repetitions per training session, respectively) (Saez de Villarreal Saez et al., 2009, 2010); however, the effectiveness of even lower volumes (7 to 36 ground contacts per training session) was shown when performed on multiple occasions per week and supplemented by other strength and conditioning methods (Cook et al., 2013; Loturco et al., 2015), which is typical for real-life training programs. Finally, rest duration has been shown to be one of the key factors influencing fatigue-potentiation effects in jumping (Cazás-Moreno et al., 2021; Lowery et al., 2012; Wilson et al., 2013). Therefore, it is possible that shorter inter-repetition rest durations would be necessary to observe impaired performance due to cumulative fatigue in our experimental sample. The inter-repetition rest duration in this experiment was selected based on pilot testing as the shortest inter-repetition rest duration deemed safe to perform landing, regaining stability, stepping backwards over the hurdle or off the box while holding the dowel across the shoulders, and to assume the proper position before the next repetition. Therefore, using 10-second timer resulting in jumping frequency of 6 jumps per minute with ~8 seconds of inter-repetition rest would be realistically applicable and safe in training practice. On the other hand, replicating this experiment using greater jumping frequency in safe manner to tease-out higher levels of cumulative fatigue would provide some valuable insights for training practice. This would be possible by substituting linear position transducer with wireless accelerometer-based device or 3D kinematics and therefore removing the constraints of the wire attached to the dowel, also allowing the participants to use arm swing. Furthermore, it would be valuable to eliminate the need to return to the starting position after every jump. This could be achieved by performing multiple consecutive jumps by using jumps over multiple hurdles or jumps up the set of stairs or up the multiple boxes of increasing height.

8.3 Effects of inter-repetition rest duration across a set of repeated jumps

The results of the experiment associated with the second data collection support our primary hypothesis, indicating that an increase in inter-repetition rest duration within a set of plyometric lower body exercise could have a protective effect against acute fatigue-related reductions of jumping performance. Similarly, increased inter-repetition rest duration could help manage the magnitudes of physiological responses, RPE, and recovery duration. The participants reported significantly lower subjective exertion, measured via RPE scale, following the experimental protocols with longer inter-repetition rest durations. No differences in RPE were reported only between R0c and R0i, and between R8 and E12 protocols. In fact, the effects of R0c and R0i protocols were similar for most of the dependent variables. Allowing a 4-second inter-repetition rest duration increased participants' ability to maintain high level of performance, lowered physiological responses, and shortened recovery durations. However, increasing the inter-repetition rest duration to 8 seconds had only marginal benefits, including lower RPE, lower blood lactate concentration, lower peak heart rate, and faster heart rate recovery.

Our results align with previous research demonstrating significant positive effects of longer inter-repetition rest durations on maintaining performance and reducing markers of cumulative fatigue (Chamari et al., 2001; Kramer et al., 2019; Moreno et al., 2014; Pereira, de Freitas, et al., 2009; Pereira et al., 2008; Pereira, Morse, et al., 2009). Although, some of the previous studies focused mainly on the ability of longer inter-repetition rest duration to increase the number of jumps to failure (Pereira, de Freitas, et al., 2009; Pereira, Morse, et al., 2009) and using repeated jumps as a conditioning modality (Kramer et al., 2019), In contrast, our experiment aimed to explore the potential of inter-repetition rest to optimize explosive strength training, similar to two aforementioned studies (Chamari et al., 2001; Moreno et al., 2014; Pereira et al., 2008).

One of these studies demonstrated that 14 to 17 seconds of inter-repetition rest allowed competitive volleyball players to reach physiological steady state during 30 volleyball spikes (Pereira et al., 2008). The physiological steady state in this study was determined via heart rate, blood lactate concentration, and number of repeated jumps to failure. Additionally, the authors concluded that an 8-second rest was too short, and a 20-second rest was unnecessarily long for the given task. However, the authors mention unpublished pilot study based on which the 8-second rest duration was set. The reported outcome of this pilot study showed that the durations shorter than 3-seconds led to *important changes to subsequent performance,* but 8-second rest allowed sustained performance throughout the set of 30 repeated spikes. Considering the results of study by Pereira et al. together with the outcomes of their pilot testing, our results show similar outcomes. Being that 4 to 8 seconds of inter-repetition rest could sustain maximal effort jumping performance across 50 CMJs, with no further benefits seen with a 12-second rest duration. Nevertheless, it is important to stress that the aforementioned study was mainly searching for physiological steady state, as in our case, maintaining high levels of performance while not putting much emphasis on achieving physiological steady state. Furthermore, there were some differences in demands of the experimental tasks. In our experiment the participants simply remained in upright standing position but in the study by Pereira et al. the participants had to perform a run up preceding every jump which required them to ambulate back to the starting position after every repetition. Lastly, no target was used in our experiment, the participants were only instructed to jump as high as possible on every repetition and an external verbal motivation was provided by researchers throughout the trial. On the other hand, participants in Periera et al. were required to spike a volleyball tossed to a target height by an experienced person, which could have provided higher motivation but simultaneously introduce higher demands as the position of the ball could vary slightly between the repetitions.

The study authored by Moreno et al. (Moreno et al., 2014), reported that using cluster sets (4 sets of 5 jumps with 30 seconds of inter-set rest and 10 sets of 2 jumps with 10 seconds of inter-set rest) was an effective strategy in preventing the loss of power, take-off velocity, and jump height across 20 CMJs compared to a traditional set configuration (2 sets of 10 jumps with 90 seconds of inter-set rest). Additionally, the authors note that the work-to-rest ratio was much larger in the traditional set (1:9) compared to both conditions involving cluster sets (1:6 and 1:5). This could have impacted the power output of individual repetitions as it fell much below the baseline in later stages of each traditional sets but recovered fully for initial repetitions of the second set. On the other hand, in cluster set conditions the power output never fell as low as in traditional set but remained slightly below baseline for most of the repetitions (Moreno et al., 2014). The results of our experiment show performance being sustained across all 50 repetitions with inter-repetition rests of 4 seconds which yielded work-to-rest ratio between 1:2.6 and 1:4, depending on a duration of single repetition for individual participants. Additionally, no major benefits were seen in our experiment when the work-to-rest ratios increased to values ranging from 1:5.3 to 1:8 in the condition involving 8-second inter-repetition rest, which were most closely resembling those reported by Moreno et al. However, breaking sets of continuous jumps into discrete repetitions separated by a rest interval leads to slower eccentric velocities, as shown in the Figures 23 and 24 above, consequently resulting in lower pre-tension and decreased effectiveness of stretch-shortening cycle (Moran & Wallace, 2007).

The pre-tension during continuous CMJs is greater than that in a single CMJ due to a faster eccentric phase and greater ground reaction force resulting in larger involvement of the series elastic components and stretch reflexes to augment jumping performance (Nicol et al., 2006; Turner & Jeffreys, 2010). This positive effect of a rebound jump is partially lost when performing discrete CMJ repetitions; however, it seems to be compensated by increased available training volume due to the delayed onset of fatigue-related performance impairments (Figures 17, 20, 21, and 22). This is supported by previous research, showing significantly increased number of jumps to failure associated with longer inter-repetition rest durations (Pereira, de Freitas, et al., 2009; Pereira, Morse, et al., 2009). In our experiment, we attempted to compare continuous jump (R0c) with intermittent jumps (R4, R8, and R12). Although, due to large differences in stretch-shortening cycle intensity and an additional squatting movement required to reach upright standing posture after each repetition of intermittent jumps. Therefore, we included a fourth intermittent condition with no passive inter-repetition rest (R0i). The R0i condition bears little resemblance to real-life training practices compared to the other protocols but serves as a bridge between the continuous and intermittent conditions.

Contrary to our expectations, comparison between the R0c and R0i conditions revealed no particularly important differences in initial performance (G1 in figures 17, 20, 21, and 22), performance changes related to cumulative fatigue (Figures 17 to 24), post-exercise recovery (Figures 25 to 28), or perceived exertion (Figure 29). Two factors could potentially explain the lack of differences between R0c and R0i conditions: I) greater pre-tension in R0c having a smaller than expected positive effect, or II) this positive effect being evident only during the initial ~2-4 repetitions, in which case this effect could be masked by analyzing the average values of five consecutive repetitions.

In the context of training efficacy, our results suggest that a 4-second inter-repetition rest duration for up to 50 CMJs yields the most benefits if fatigue reduction is the goal. Only marginal benefits seem to result from doubling the rest duration to 8 seconds, which might not be worthwhile when considering the significant increase of total exercise duration. Given the substantial difference in outcomes between 0 and 4 seconds of inter-repetition rest, attention should be turned to the rest durations filling this gap. A study examining 1-, 2-, and 3-second inter-repetition rest would be valuable for broadening our understanding of the three-way relationship between exercise volume, inter-repetition rest duration, and cumulative fatigue in vertical jumping.

The limitations of this experiment involve the analysis of averaged data from five consecutive jumps. While this approach facilitated reduction in the number of data points enhancing clarity of results, it simultaneously led to some loss of detail. Furthermore, this experiment would benefit from additional conditions including inter-repetition rest durations of 1, 2, and 3 seconds and exercise variations such as drop jump from a height matching participant's maximal CMJ height which would provide fast stretch-shortening cycle performed in intermittent fashion and therefore resolve aforementioned problem with mismatched stretch-shortening cycle intensity between continuous and intermittent CMJ. Unfortunately, adding those conditions was beyond our possibilities in this experiment as those would dramatically increase the number of visits and amount of testing material needed. We originally planned to include measurements of ground reaction forces; however, it was not possible as only portable force platforms were available during the data collection which would disproportionally increase the injury risk due to creating relatively small landing area slightly elevated above the surrounding flooring. Because we expected a significant increase of fatigue during some of the experimental conditions, we deemed such landing conditions inappropriate. Additionally, the 15-minute post-intervention recovery period proved insufficient for capturing the complete recovery of the conditions generating the highest levels of fatigue. It could be valuable, for future research, to implement an extended recovery period. That being said, incorporating multiple CMJs throughout the recovery period would be valuable to track the recovery of jumping performance, providing a complementary perspective to the assessment of physiological variables.

8.4 Effects of athlete characteristics on jumping performance.

The correlation analysis revealed several significant relationships between maximal jumping performance and anthropometric characteristics (Appendix 4). However, none of these relationships were strong (all r ≤0.62). Only one correlation – between lower leg length and jump height – showed a significant moderate positive relationship across all three jump types (BJ, HJ, and CMJ). Therefore, our hypothesis regarding the effects of body fat percentage and body weight on jumping performance was not supported.

Our results add to the diverse body of research on this topic. For example, a significant positive moderate correlation was reported between CMJ performance and body fat percentage in professional male athletes (Emamian Shirazi et al., 2022). Conversely, other studies found no relationship between body fat percentage and CMJ height (Ishida et al., 2021) or power outputs during SJ and CMJ in young male soccer players (Ishida et al., 2021) and female Division I volleyball players (Legg et al., 2021). The discrepancies in these outcomes might be influenced by confounding factors such as training status, training history, or kinematic aspects of the jump (e.g., speed and depth of countermovement, positions of main body segments, etc.)

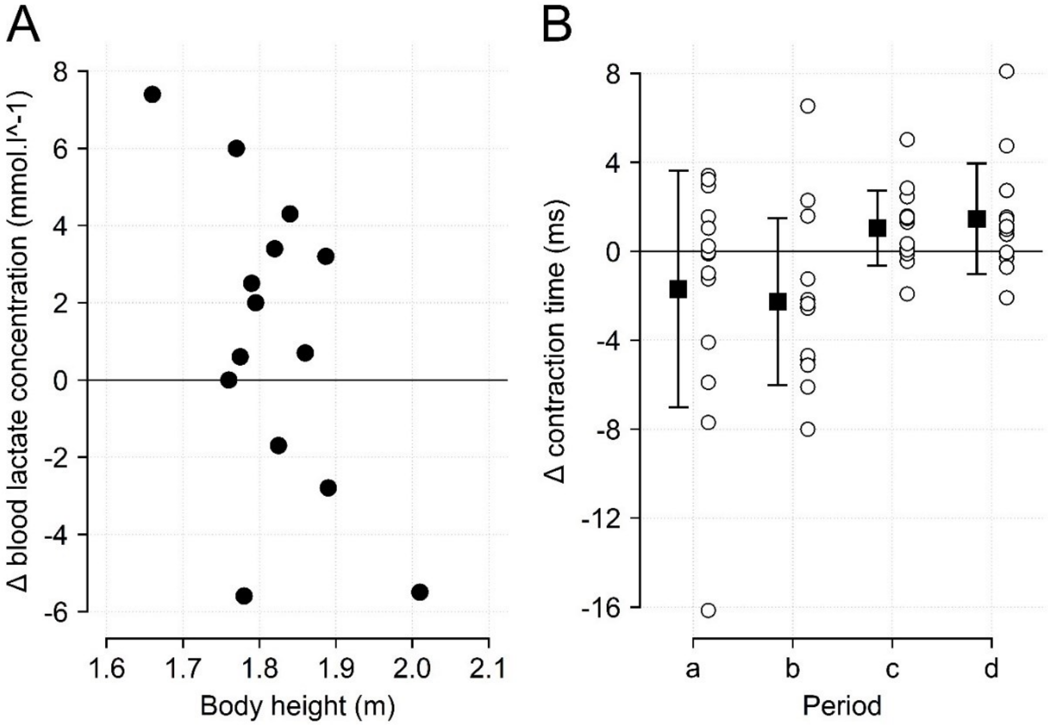
Similarly, body mass was not correlated with CMJ performance (Emamian Shirazi et al., 2022), but showed significant moderate positive relationship with peak power generated during CMJ, though not in unloaded SJ (Ishida et al., 2021). The benefits of greater body mass for power production during a countermovement may stem from the increased potential to generate high pretension in the series elastic component during the stretch shortening cycle (Turner & Jeffreys, 2010).

The significant positive correlations between the lower led length and jumping height in all three jump types could be due to biomechanical advantages. A longer shank likely helps generate greater tension in the Achilles tendon and plantar flexor muscles by providing a larger lever during the eccentric and amortization portions of the countermovement. It has been shown that a powerful pre-stretch of an active muscle within muscle-tendon complex results in greater power outputs (Komi, 2003). However, our finding contrasts with the outcomes of previous study, which found that foot length, but not the tibia length, was a significant predictor of vertical jump performance in recreationally trained men (Davis et al., 2006). Thus, while certain anthropometric parameters might influence vertical jump performance, our analysis did not establish a strong enough link to make confident practical recommendations.

The second part of our correlation analysis explored the relationships between anthropometric characteristics (height, weight, fat percentage, leg length, and leg length discrepancy) and performance loss during 50 continuous CMJs. As with maximal jumping performance, anthropometric characteristics appeared mostly unrelated to performance changes during and after a fatiguing set of continuous CMJs. However, there were significant moderate negative correlations between RPE and both body height and body weight. Although previous study evaluating the relationship between anthropometric parameters and RPE during small-sided basketball games in children, found these correlations to be inconclusive (Clemente et al., 2019). Besides RPE, body height and weight displayed moderate relationship with changes in blood lactate concentration during recovery and muscle contraction time from the 5th to the 10th minute of recovery, respectively. Taller participants might be more effective at clearing blood lactate after exercise, while heavier participants might be faster at restoring their muscle contraction time to baseline levels (Figure 28). However, data of individual participants show that this might not be the case. Instead, blood lactate concentration continued to increase throughout the post-exercise recovery for most participants and decreased only in 4 out of 14 participants (Figure 37A). Furthermore, changes in muscle contraction times from the 5th to 10th minute post-intervention were minimal compared to other time points (Figure 37B).

A significant moderate positive relationship between heart rate and body fat percentage indicated that individuals with higher relative adiposity might experience greater acute increases in heart rate during continuous jumps. This relationship, calculated using the absolute increase in heart rate, was not influenced by inter-individual differences in pre-intervention heart rate, as there was a weak, non-significant relationship between body fat percentage and pre-intervention heart rate ($r = 0.31$, $p = 0.282$). Studies on the relationship between body fat percentage and heart rate changes during and after exercise have reported mixed outcomes. For example, a study reported significantly lowered heart rate during a treadmill test in morbidly obese patients from before to one year after bariatric surgery, which resulted in significant reduction in body fat (Serés et al., 2006). Other studies found weak, non-significant relationship between body fat percentage and heart rate recovery following an incremental treadmill test in healthy adults (Jezdimirovic et al., 2017), significant moderate negative relationship between body fat percentage and heart rate recovery after all-out Wingate test in professional cyclists (Campos et al., 2012), and significantly greater decrease of heart rate following treadmill ramp test in normal-weight compared to obese older adults (Gondoni et al., 2009). Lastly, body fat percentage was significantly negatively correlated with fatigue index during multiple repeated sprint ability test in young elite badminton players (Akdogan et al., 2022). Conversely, in our experiment, body fat percentage was not significantly correlated with changes in any of the jumping performance metrics measured (Appendix 5).

Figure 37. Body height and change in blood lactate concentration during post-intervention recovery in individual participants (A), and group mean ± SD and individual data of changes in muscle contraction time at different periods during the experiment (B).



a = changes between rest and 1-minute after the last jump, b = changes between 1- and 5-minutes after the last jump, c = changes between 5- and 10-minutes after the last jump, d = changes between 10- and 15-minutes after the last jump.

Leg length displayed a significant moderate positive correlation with changes in countermovement depth during the fatiguing jumps, indicating that longer legs relative to body height might be associated with more pronounced deepening of the countermovement in the late stages of the set. However, the range of leg lengths was very small within our sample – with the minimal and maximal leg lengths separated only by 3.4 percent of body height (50.4 to 53.8 %) – possibly lowering the practical relevance of this relationship. Similarly, leg length discrepancies were generally small within our sample (ranging from 0 to 1 cm) resulting in no significant correlations with any dependent variables. While no exact cutoff for leg length discrepancy leading to functional and health problems exists (Gross, 1978), discrepancies less than 2 cm are generally well tolerated without treatment (Gordon & Davis, 2019; Gurney, 2002; Walsh et al., 2000).

Training experience and maximal CMJ height showed no significant correlations with any dependent variables in the second data collection (Appendix 6). Whereas DJ performance resulted in moderate significant positive correlation with changes in blood lactate concentrations during recovery, suggesting that better jumpers experienced either a plateau or further elevation in blood lactate concentration, unlike participants with lower DJ performance, who tended to clear some accumulated blood lactate or experienced no changes.

A fatiguing set of repeated vertical jumps significantly elevate blood lactate levels (Manojlović & Erčulj, 2019). However, there is limited evidence on post-exercise blood lactate metabolism related to jumping abilities. The further increase in blood lactate levels during post-intervention recovery observed in most participants in our experiment could be due to the very high intensity of the experimental task, which involved 50 repetitions performed within a very short duration (~1 minute). This short duration might not be sufficient to detect peak blood lactate concentration from the fingertip, as this sampling site is distant from the leg muscles which would be responsible for producing most of the blood lactate during jumping. Results from a study on blood lactate levels following the Wingate test show a similar pattern, with blood lactate continuing to rise during the recovery period and dropping after the 8th minute in most participants (Öztürk et al., 1998).

However, it is not clear why a similar relationship was not present for SJ and CMJ performance. The key difference in these jump types is the magnitude of pre-tension preceding the concentric portion of the take-off phase (McBride et al., 2008). This indicates that the ability to manage and leverage greater pre-tension via stretch-shortening cycle could be an important factor. Although more research is needed to test this theory and explain its mechanisms of influence.

SJ performance was significantly correlated with multiple dependent variables. Specifically, there were strong negative relationships with changes in mean concentric velocity and heart rate during the experimental protocol, moderate negative relationships with changes in peak concentric velocity, and moderate positive relationships with changes in mean and minimal eccentric velocities during the experimental protocol, as well as muscle belly displacement from 1 to 10 minutes of recovery. These results indicate that a higher level of SJ performance was related to greater decreases in movement speed during both concentric and eccentric portions of the take-off phases during the experimental protocol. Simultaneously, it was associated with smaller increases in heart rate during the experimental protocol and greater increase of muscle belly displacement during initial 10 minutes of recovery. As of now, the underlying mechanisms responsible for these relationships associated with SJ performance are unclear. However, similar to the discussion involving DJ performance, we assume that one of these factors could be the ability to effectively implement the stretch-shortening cycle. This is eliminated in SJ variation by prolonged isometric hold at the bottom of the countermovement preceding the concentric phase of take-off (Van Hooren & Zolotarjova, 2017).

Finally, several variables were significantly correlated with back squat 1RM performance and back squat load-velocity profile. Both absolute and relative back squat 1RMs were moderately negatively correlated with changes in countermovement depth during the experimental protocol. Specifically, individuals with higher absolute and relative maximal leg strength exhibited minimal changes in countermovement depth, whereas those with lower strength levels tended to use deeper countermovement depth in later stages of the experimental protocol. A possible explanation might be that stronger individuals are inclined towards training modalities that mimic the movement patterns used in CMJ, thus enhancing their training status and experience with such movements. If this is the case, then stronger individuals may find it easier to select an optimal countermovement depth early in the set and maintain that depth even when fatigued.

Additionally, relative back squat 1RM was strongly positively correlated with RPE, indicating that stronger individuals tended to experience higher levels of subjective exertion. This could be due to suspected differences in habitual training practices among our participants. All participants were experienced in resistance training, meeting the inclusion criterion of relative back squat 1RM equal to or greater than their body weight. However, the relative strength ranged from 1.3 to 2 times their body weight. Furthermore, the diverse sporting backgrounds in our sample hint that, while strength training was a common part of their training regime, the specific methods, aims, and roles of strength training likely varied between participants. Since training history has been linked to session RPE (Barroso et al., 2014; Winborn et al., 1988), future research could benefit from a more detailed investigation of participants' habitual strength training practices.

The slope of the back squat load-velocity profile was significantly correlated only with changes in heart rate during the experimental protocol. This moderate positive correlation indicates that a steeper load-velocity profile – defined as a greater reduction in mean concentric velocity per unit of added load – was associated with a lower increase of heart rate throughout the fatiguing plyometric intervention. This could be similar to the effect seen with maximal strength, which could be related to the nature of habitual training and its specific adaptations. Training involving higher volumes of lower resistance plyometric actions or intermittent bouts of short high-effort actions, such as in team sports and long-distance running, would closely resemble the requirements of our experimental protocol and likely result in steeper load-velocity profiles (Sheppard et al., 2008). On the other hand, training involving actions against higher resistance, such as training for maximal strength development, would likely create adaptations which would result in minimal decrease of velocities with increasing external resistance; therefore, a flatter load-velocity profile (Sheppard et al., 2008). Thus, lower steepness of load-velocity profile might indicate less training experience with specific physical demands imposed by the set of 50 continuous CMJs.

Analysis of subgroup data revealed some significant differences, although small sample size exposes these results to higher risk of type II error. Therefore, some of the comparisons discussed in the following paragraphs might be falsely indifferent.

Splitting our sample into subgroups based on the level of maximal lower body strength relative to the individual's body weight showed that jump height decreased in both higher and lower strength subgroups (Appendix 7). However, the decrease reached a significant level only in the higher strength subgroup. This could be affected by a significant deepening of countermovement throughout the experimental protocol in the lower strength subgroup. The deeper countermovement could have led to a smaller loss of concentric and eccentric velocities in the lower strength subgroup throughout the intervention, demonstrated by non-significant and significant large effects of strength level on concentric and eccentric velocity changes, respectively. The lower strength subgroup also demonstrated significantly lower RPE compared to the higher strength subgroup, which could be influenced by the aims and parameters of participants' habitual training, as discussed previously. Furthermore, there were no significant differences in time to peak velocity, blood lactate concentration, heart rate, and localized muscle contractile properties between the higher and lower strength subgroups. Similarly, none of the dependent variables differed between subgroups with higher and lower steepness of the back squat load-velocity profile (Appendix 8).

Subgroups based on SJ and CMJ performances yielded very similar results (Appendices 9 and 10, respectively). In both cases, jump height at the beginning of the intervention was significantly greater in the higher jump subgroup. Then jump height significantly decreased in both higher and lower jump subgroups throughout the intervention, but the differences in jump height between subgroups at the final stage of the intervention were insignificant. Results for mean and peak concentric velocities were analogous to those of jump height. Initially, there were large effects of performance level, with faster velocities in the higher jump subgroups. Both subgroups significantly decreased concentric velocities during the intervention, resulting in non-significant differences between subgroups at the end of the intervention. Also, there were non-significant large effects for a greater loss of speed during eccentric portion of a countermovement in the higher jumpers compared to the lower jump subgroups throughout the intervention. Lastly, there were large between-subgroup effects for greater pre-intervention heart rates in the higher jumping subgroups. However, there were no differences in heart rates between subgroups at the end of the intervention and after 5 minutes of recovery. Results of previous studies show similar outcomes between jumping abilities and anaerobic power assessment, as there were no differences in fatigue index and peak heart rate during the Wingate test between groups of young male volleyball players differing in their jumping performance (Nikolaidis et al., 2017). Also, there was no significant correlation between the fatigue index derived from the Wingate test and both SJ and CMJ performance in adolescent and adult female volleyball players (Nikolaidis et al., 2016).

Outcomes of subgroups based on DJ performance differed from those of SJ and CMJ, showing a non-significant moderate effect for greater loss of concentric velocity in the higher jumping subgroup. However, this was not coupled with any other differences including jump height, eccentric velocities, RPE, heart rate, blood lactate concentration, or muscle contractile properties (Appendix 11). We believe that this difference might result from the generally low ability of our sample to utilize higher pre-tension associated with drop jumps (McBride et al., 2008), as seen by the lower mean performance in DJ compared to CMJ (Table 10). Furthermore, subgroups based on the amount of performance potentiation gained from incorporating the stretch-shortening cycle (i.e., the difference between SJ and CMJ performance) showed non-significant moderate effects for greater loss of eccentric and concentric speed in subgroups with lower potentiation (Appendix 12). Therefore, it might be beneficial to possess greater ability to effectively utilize elevated pre-tension via the stretch-shortening cycle to reduce loss of performance during continuous high-effort jumping tasks.

Although our sample might not be heterogenous enough, or this effect might not be large enough, to conclusively confirm or reject this without greater statistical power.

9 General summary and conclusion

The outcomes of the experiments included in this dissertation offer several important takeaways for training practice and future research. The first experiment, which compared three common plyometric exercises, demonstrated that jumps onto a box of similar height to that of a maximal CMJ performance could reduce peak impact forces by approximately 50 percent compared to HJ and CMJ. This finding has practical implications for load management, especially during periods of increased competitive load and for athletes with lower tolerance to eccentric loading. Furthermore, this experiment revealed that overcoming an obstacle in BJ and HJ led to significant adjustments in key take-off variables, such as shallower countermovement depth, shorter time to peak concentric power and velocity, and greater peak horizontal force, compared to CMJ. Meanwhile, other key parameters – peak and mean concentric velocity, peak vertical and resultant force, rate of force development, and total impulsion time – remained unaffected. Therefore, the presence of an obstacle mainly alters the direction of force production and the countermovement, measured as the vertical displacement of the shoulders. However, the similar magnitudes and rates of resultant take-off forces, as well as similar concentric velocities, suggest that these jump types might provide comparable stimuli for explosive strength training of lower extremities.

The second experiment aimed to determine whether reduced peak impact forces could reduce performance losses due to cumulative fatigue during a set of repeated vertical jumps. The outcomes do not support our hypothesis that reducing impact forces would be beneficial for managing fatigue-related changes, as no loss of performance was observed in the HJ condition. Interestingly, both the BJ and HJ conditions displayed initial potentiation followed by stabilization of jumping performance. This was likely due to ~8 seconds of inter-repetition rest duration, which was probably sufficient to prevent build-up of cumulative fatigue in individuals experienced in plyometric training.

The third experiment highlights the effectiveness of manipulating inter-repetition rest duration to delay acute onset of fatigue-related performance decline during repeated high-effort CMJs. As expected, conditions without inter-repetition rest led to a rapid onset of negative changes, which continued throughout the intervention. However, no particularly important differences were observed between the variations characterized by higher and lower intensity of the stretch-shortening cycle. Conversely, a 4-second inter-repetition rest enabled performance to be sustained across the whole set of 50 CMJs. Increasing inter-repetition rest to 8 and 12 seconds further reduced perceived exertion, lowered post-exercise blood lactate concentration, and increased jump height during the intervention. However, coaches should consider the cost and benefits of such programming decisions, as extending inter-repetition rest beyond what is necessary will prolong exercise duration without additional training benefits. Consequently, based on our data, coaches and athletes aiming to enhance lower body power through repeated CMJs can effectively maintain performance, minimize subjective exertion, and ensure an effective use of training time with a 4-second inter-repetition rest in active young men experienced in plyometric training.

Lastly, the correlation and subgroup analyses provided insights into the complex relationships between anthropometric characteristics, lower extremity strength levels, jumping performances, and ability to resist loss of performance across a high-volume set of continuous jumps. Significant moderate to strong correlations were identified, such as between lower leg length and jump height, and between squat jump performance and velocity changes during continuous jumps. However, replication of these results and exploration of potential underlying mechanisms (e.g., habitual training practices) should precede formulating concrete practical recommendations. Our findings underscore the multifactorial nature of maximal and repeated jumping performance.

10 References

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Appendix 1: Ethics committee approval

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Žádost o vyjádření Etické komise UK FTVS

k projektu výzkumné, kvalifikační či seminární práce zahrnující lidské účastníky

Název projektu: Efekt délky odpočinku v tréninku explozivní síly dolních končetin

Forma projektu: výzkumná práce – doktorská práce

Období realizace: září 2021 – září 2023

Výzkum bude realizován v souladu s platnými epidemiologickými opatřeními Ministerstva zdravotnictví ČR.

Předkladatel: Mgr. Martin Tino Janikov, UK FTVS katedra fyziologie a biochemie

Hlavní řešitel: Mgr. Martin Tino Janikov, UK FTVS katedra fyziologie a biochemie

Místo výzkumu (pracoviště): UK FTVS katedra fyziologie a biochemie, UK FTVS posilovna, Sportovní centrum evropská

Vedoucí práce (v případě studentské práce): James J. Tufano, Ph.D., CSCS*D, UK FTVS katedra fyziologie a biochemie

Finanční podpora:

Popis projektu: Cílem projektu je kvantifikace efektu různých délek odpočinku na kinetické parametry výskoku a únavu v tréninku explozivní síly dolních končetin. Jedná se o vyvážený opakovaný randomizovaný experiment, se sběrem dat v laboratorních podmínkách. Projekt je složen z 2 sběrů dat, které poslouží pro cca 4 publikační výstupy. Před každým sběrem dat účastníci absolvují jeden familiarizační den, který bude obsahovat kontrolu splnění podmínek pro zařazení do výzkumu, měření antropometrických parametrů, konkrétně: tělesné výšky, tělesné hmotnosti a tělesné kompozice metodou bioelektrické impedance InBody 770 (InBody, Jižní Korea). Následně účastníci provedou standardizované rozcvičení, test maximálního výskoku z dřepu, výskoku s protipohybem a výskoku po seskoku z výšky 32 cm, a test 1 opakovacího maxima dřepu s velkou činkou na zádech. Familiarizační den bude zakončen praktickým seznámením účastníků s pohybovými testy dalších testovacích dnů. V rámci prvního sběru dat budou měřeny opakované maximální výskoky, přeskoky překážky a výskoky na bednu. Všechny 3 varianty v provedení z místa bez nákroku a bez přidaného odporu, s dřevěnou tyčí drženou na zádech. Opakované maximální výskoky budou provedeny v objemu 50 opakování v pěti variantách odpočinku mezi výskoky: 0 sekund kontinuálně a 0, 4, 8, a 12 sekund přerušovaně. Přes překážku a na bednu o shodné výšce 50 cm budou provedeny výskoky v objemu 30 opakování. Před sérií opakovaných výskoků bude měřená tepová frekvence pomocí hrudního pásu (Polar Electro, Finsko), koncentrace krevního laktátu z kapilární krve (BUSIMEDIC SL, Španělsko), a rychlost svalové kontrakce m. vastus laterális dominantní končetiny pomocí tensiomyografu (TMG BMC Ltd., Slovinsko). Tepová frekvence bude následně měřená v průběhu, ihned po a 5, 10 a 15 minut po opakovaných výskocích. Rychlost svalové kontrakce bude měřená ihned po a 5, 10 a 15 minut po opakovaných výskocích. Koncentrace krevního laktátu bude měřena ihned po a 15 minut po opakovaných výskocích. Jednotlivé varianty budou testovány v různé dny s odpočinkem minimálně 48 hodin. Druhý sběr dat bude ve většině směrů identický s prvním. Jediný rozdíl bude tvořit přidaná zátěž formou zátěžové vesty. Hmotnost zátěžové vesty bude odpovídat 10 % tělesné hmotnosti účastníka. Tato intenzita byla zvolená na základě předešlého prozkoumání publikované literatury k danému tématu (https://pubmed.ncbi.nlm.nih.gov/12560951/; https://oapub.org/edu/index.php/ejep/article/view/982). Soubor účastníků pro jednotlivé části výzkumu se nebude nutně skládat ze stejných jedinců.

Charakteristika účastníků výzkumu: cca 20 studentů UK FTVS mužského pohlaví. Podmínkou účasti je platná zdravotní prohlídka u tělovýchovného lékaře a předchozí zkušenost se silovým tréninkem, dále zkušenost s tímto charakterem zátěže a typem cvičení. Pouze účastníci se zkušeností s plyometrickým tréninkem s přidanou zátěží se mohou účastnit druhého sběru dat. Kontraindikací pro účast ve výzkumu je neschopnost bezbolestného provedení maximálního vertikálního výskoku a dřepu s velkou činkou na ramenou. Další kontraindikací je neschopnost provedení dřepu do hloubky, ve které je stehenní kost v horizontální pozici anebo probíhající rehabilitační proces po zranění nebo operaci. Testování se nezúčastní osoby s akutním (zejména infekční), astmatickým a kardiovaskulárním onemocněním s jakýmkoliv onemocněním či omezením pohybového aparátu a v rekonvalescenci po onemocnění či úrazu. Výběr účastníků a kontrolu kontraindikací provede předkladatel žádosti ve spolupráci s fyzioterapeutem.

Zajištění bezpečnosti: Výzkum zahrnuje neinvazivní metody sběru dat s výjimkou měření koncentrace krevního laktátu. Pro stanovení koncentrace laktátu v kapilární krvi, je potřeba odebrat respondentům vzorek periferní krve (z prstu). Jelikož se jedná o invazivní metodu sběru dat, všechny odběry budou prováděny standardním postupem pro odběr biologického materiálu. Odběry krve bude provádět kvalifikovaný zdravotník.

Rizika spojená se sběrem dat jsou přiměřená k povaze pohybových aktivit zahrnutých v tomto výzkumu. Použité testy můžou působit nepohodlí ve formě svalové únavy dolních končetin. Protože tento výzkum zahrnuje soubor silově a plyometricky trénovaných jedinců, a jak objem, tak intenzita použitá v tomto výzkumu je nižší v porovnání s běžným silově-vytrvalostním tréninkem, předpokládáme, že kloubním strukturám a páteři subjektů nehrozí signifikantní riziko.

Je možné očekávat výskyt natažení svalů, kloubním poraněním dolních končetin plynoucích z explozivní podstaty pohybového úkonu. Riziko natažení svalu bude minimalizováno zařazením důkladného rozcvičení před každým sběrem dat. Všichni účastníci výzkumu, jakožto studenti tělovýchovného oboru, jsou držiteli platné zdravotní prohlídky sportovním lékařem, která jim povoluje bezpečnou participaci v pohybových testech obsažených v našem výzkumu. Každému sběru dat bude předcházet standardizované rozcvičení. Rizika prováděného výzkumu nebudou vyšší než běžně očekávaná rizika u aktivit a testování prováděných v rámci tohoto typu výzkumu. Testování bude probíhat za standardních bezpečnostních podmínek.

Etické aspekty výzkumu: Výzkumu se neúčastní příslušníci žádné vulnerabilní skupiny osob. Cílem tohoto výzkumu je kvantifikovat efekt různých délek odpočinku v průběhu série opakovaných maximálních výskoků. Doufáme, že výsledky tohoto výzkumu poskytnou návod pro efektivní redukci únavy v tréninku výskoků, čím přispějí k zvýšení bezpečnosti a efektivity tohoto typu tréninku v praxi.

Potenciální střet zájmů: Předkladatel projektu nemá soukromý zájem na výsledku výzkumu. Integrita a důvěryhodnost výzkumu není ohrožena, protože tento výzkum je realizován v rámci doktorského studia předkladatele a žádný z možných výsledků výzkumu nebrání publikaci výsledků a dokončení studia. Předkladatel nemá vazbu na žádnou společnost nebo metodiku, která by byla zvýhodněná jedením z možných výsledků tohoto výzkumu. Předkladatel ani žádný člen výzkumného týmu nemá soukromý zájem na výsledku výzkumu a ani výzkum nevede k osobnímu prospěchu.

Ochrana osobních dat: Data budou shromažďována a zpracovávána v souladu s pravidly vymezenými nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů. Budou získávány následující osobní údaje: věk, tělesná výška, tělesná hmotnost, parametry tělesné kompozice ve formě výsledku bioelektrické impedance, délky tělesných segmentů, výsledky pohybových testů blíže popsaných v části popis projektu. Data budou bezpečně uchována na heslem zajištěném počítači. Přístup k nim bude mít předkladatel projektu.

Uvědomuji si, že text je anonymizován, neobsahuje-li jakékoli informace, které jednotlivě či ve svém souhrnu mohou vést k identifikaci konkrétní osoby – budu dbát na to, aby jednotlivé osoby nebyly rozpoznatelné v textu práce. Osobní data, která by vedla k identifikaci účastníků výzkumu, budou bezprostředně do 1 dne po testování anonymizována pomocí číselných kódů.

Získaná data budou zpracovávána, bezpečně uchována a publikována v anonymní podobě v disertační práci předkladatele, v odborných časopisech, případně v úložištích dat, monografiích a prezentována na konferencích, případně budou využita při další výzkumné práci na UK FTVS.

Pořizování fotografií/videí/audio nahrávek účastníků: Během výzkumu nebudou pořizovány žádné fotografie, audionahrávky ani videozáznam.

V maximální možné míře zajistím, aby získaná data nebyla zneužita.

Text informovaného souhlasu (IS): přiložen

Povinností **všech účastníků výzkumu na straně řešitele** je chránit život, zdraví, důstojnost, integritu, právo na sebeurčení, soukromí a osobní data zkoumaných subjektů, a podniknout k tomu veškerá preventivní opatření. Odpovědnost za ochranu zkoumaných subjektů leží vždy na účastnících výzkumu na straně řešitele, nikdy na zkoumaných, byť dali svůj souhlas k účasti na výzkumu. Všichni účastníci výzkumu na straně řešitele musí brát v potaz etické, právní a regulační normy a standardy výzkumu na lidských subjektech, které platí v České republice, stejně jako ty, jež platí mezinárodně.

Potvrzuji, že tento popis projektu odpovídá návrhu realizace projektu a že při jakékoli změně projektu, zejména použitých metod, zašlu Etické komisi UK FTVS revidovanou žádost.

V Praze dne: 25. 6. 2021 Podpis předkladatele:

Vyjádření Etické komise UK FTVS

Složení komise: **Předsedkyně:** doc. PhDr. Irena Parry Martínková, Ph.D.
Členové: prof. MUDr. Jan Heller, CSc. Mgr. Eva Prokešová, Ph.D.
prof. PhDr. Pavel Slepička, DrSc. Mgr. Tomáš Ruda, Ph.D.
PhDr. Pavel Hráský, Ph.D. MUDr. Simona Majorová

Projekt práce byl schválen Etickou komisí UK FTVS pod jednacím číslem: 138/2021

dne: 25.6. 2021

Etická komise UK FTVS zhodnotila předložený projekt a **neshledala rozpory** s platnými zásadami, předpisy a mezinárodní směrnicemi pro provádění výzkumu zahrnujícího lidské účastníky.

Řešitel projektu splnil podmínky nutné k získání souhlasu Etické komise UK FTVS.

UNIVERZITA KARLOVA
Fakulta tělesné výchovy a sportu
José Martího 31, 162 52, Praha 6
– 20 –

razítko UK FTVS

podpis předsedkyně EK UK FTVS

Appendix 2: Informed consent form

INFORMOVANÝ SOUHLAS

Vážený pane,

v souladu se Všeobecnou deklarací lidských práv, nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů a dalšími obecně závaznými právními předpisy *(jakož jsou zejména Helsinská deklarace, přijatá 18. Světovým zdravotnickým shromážděním v roce 1964 ve znění pozdějších změn (Fortaleza, Brazílie, 2013); Zákon o zdravotních službách a podmínkách jejich poskytování (zejména ustanovení § 28 odst. 1 zákona č. 372/2011 Sb.) a Úmluva o lidských právech a biomedicíně č. 96/2001, jsou-li aplikovatelné),* Vás žádám o souhlas s Vaší účastí ve výzkumném projektu na UK FTVS v rámci disertační práce s názvem: Efekt délky odpočinku v tréninku explozivní síly dolních končetin, prováděné na Katedře fyziologie a biochemie Fakulty tělesné výchovy a sportu Univerzity Karlovy.

Popis projektu: Projekt bude probíhat v období září 2021 až září 2023. Projekt je zpracován bez finanční podpory. Cílem projektu je kvantifikace efektu různých délek odpočinku na kinetické parametry výskoku a únavu v tréninku explozivní síly dolních končetin. Budete se účastnit měření tělesné výšky, tělesné hmotnosti a tělesné kompozice metodou bioelektrické impedance. Následně proběhne testování maximálního výskoku z dřepu, výskoku s protipohybem a výskoku po seskoku z výšky 32 cm, a test 1 opakovacího maxima dřepu s velkou činkou na zádech. Další sběr dat proběhne ve dvou fázích.

První fáze obsahuje test 50 opakovaných výskoků s různými dobami odpočinku v náhodném pořadí (0 sekund kontinuálně, 0, 4, 8 a 12 sekund přerušovaně), 30 opakovaných výskoků na 50 cm vysokou bednu a 30 opakovaných výskoků přes 50 cm vysokou překážku s intervalem odpočinku v délce 10 s. Dále budou měřené hodnoty tepové frekvence, koncentrace krevního laktátu a rychlosti kontrakce svalu. Tepová frekvence bude měřená neinvazivně pomocí hrudního pásu před, v průběhu a 0, 5, 10 a 15 minut po sérii opakovaných výskoků. Koncentrace krevního laktátu bude měřená invazivně z kapénky kapilární krve, která bude odebrána lékařem z konečku prstu před, 0 a 15 minut po sérii opakovaných výskoků. Všechny odběry budou prováděny standardním postupem pro odběr biologického materiálu. Odběry krve bude provádět kvalifikovaný zdravotník.

Rychlost svalové kontrakce bude měřená neinvazivně pomocí přístroje TMG, který pomocí elektrod stimuluje vnější hlavu čtyřhlavého stehenního svalu na dominantní dolní končetině a pomocí snímače zaznamená rychlost reakce svalu. Rychlost svalové kontrakce bude měřená vyškoleným pracovníkem laboratoře před a 0, 5, 10 a 15 minut po sérii opakovaných výskoků. Testování bude probíhat za standardních bezpečnostních podmínek a bude zajištěna hlavním řešitelem a pracovníky laboratoře.

Druhá fáze testování bude probíhat ve většině směrů identicky. Jediným rozdílem bude provedení všech skoků se zátěžovou vestou o hmotnosti 10 % Vaší tělesné hmotnosti.

Každá fáze testování bude trvat přibližně 60 minut a proběhne v samostatný testovací den. Mezi jednotlivými dny bude dodržen odpočinek minimálně 48 hodin.

Rizika spojená se sběrem dat jsou přiměřená k povaze pohybových aktivit zahrnutých v tomto výzkumu. Použité testy můžou působit nepohodlí ve formě svalové únavy dolních končetin. Možný risk pro kloubní struktury a páteř jsou redukovány relativně nízkou intenzitou a objemem použitým v tomto výzkumu v porovnání s celkovým objemem běžné tréninkové jednotky. Riziko svalových zranění jako například natažení svalu, kloubního poranění dolních končetin bude redukováno důkladným rozcvičením před každým sběrem dat.

Podmínkou Vaší účasti ve výzkumu je platná zdravotní prohlídka u tělovýchovného lékaře a předchozí zkušenost se silovým tréninkem, dále zkušenost s tímto charakterem zátěže a typem cvičení. Pokud se účastníte druhé části sběru dat, musíte mít zkušenost s tréninkem výskoku se zátěžovou vestou. Projektu se nemůžete účastnit pokud, nejste schopní bezbolestně provádět maximální vertikální výskok nebo dřep s velkou činkou na ramenou. Další kontraindikací je neschopnost provedení dřepu do hloubky, ve které je stehenní kost v horizontální pozici nebo je u Vás momentálně probíhající rehabilitační proces po zranění nebo operaci. Testování se nezúčastní osoby s akutním (zejména infekční), astmatickým a kardiovaskulárním onemocněním s jakýmkoliv onemocněním či omezením pohybového aparátu a v rekonvalescenci po onemocnění či úrazu.

Očekávaný přínos výzkumného projektu spočívá ve zkvalitnění tréninkového procesu explozivní síly dolních končetin. Výsledky tohoto výzkumu poskytnou důležité informace týkající se minimalizace únavy v tréninkové praxi, což povede k zvýšení efektivity a bezpečnosti tréninku explozivní síly dolních končetin.

Účastníkům není za účast na výzkumném projektu poskytnutá finanční či jiná odměna.

S celkovými výsledky a závěry výzkumného projektu se můžete seznámit v disertační práci v Digitálním repozitáři UK, nebo na e-mail adrese: tino@tinojanikov.com

Ochrana osobních dat: Data budou shromažďována a zpracovávána v souladu s pravidly vymezenými nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů. Budou získávány následující osobní údaje: věk, tělesná výška, tělesná hmotnost, parametry tělesné kompozice ve formě výsledku bioelektrické impedance, délky tělesných segmentů, výsledky pohybových testů blíže popsaných výše. Data budou bezpečně uchována na heslem zajištěném počítači. Přístup k nim bude mít předkladatel projektu.

Uvědomuji si, že text je anonymizován, neobsahuje-li jakékoli informace, které jednotlivě či ve svém souhrnu mohou vést k identifikaci konkrétní osoby – budu dbát na to, aby jednotlivé osoby nebyly rozpoznatelné v textu práce. Osobní data, která by vedla k identifikaci účastníků výzkumu, budou bezprostředně do 1 dne po testování anonymizována pomocí číselných kódů.

Získaná data budou zpracovávána, bezpečně uchována a publikována v anonymní podobě v disertační práci předkladatele, v odborných časopisech, případně v úložištích dat, monografiích a prezentována na konferencích, případně budou využita při další výzkumné práci na UK FTVS.

Pořizování fotografií/videí/audio nahrávek účastníků: Během výzkumu nebudou pořizovány žádné fotografie, audionahrávky ani videozáznam.

V maximální možné míře zajistím, aby získaná data nebyla zneužita.

Jméno a příjmení předkladatele a hlavního řešitele projektu: Mgr. M. Tino Janikov

Jméno a příjmení osoby, která provedla poučení: Mgr. M. Tino Janikov Podpis: ....

Prohlašuji a svým níže uvedeným vlastnoručním podpisem potvrzuji, že dobrovolně souhlasím s účastí ve výše uvedeném projektu a že jsem měl možnost si řádně a v dostatečném čase zvážit všechny relevantní informace o výzkumu, zeptat se na vše podstatné týkající se účasti ve výzkumu a že jsem dostal jasné a srozumitelné odpovědi na své dotazy. **Potvrzuji, že mám platnou zdravotní prohlídku u tělovýchovného lékaře. Jsem si vědom náročnosti silové zátěže a rizik s ní spojených. Byla mi podrobně vysvětlena veškerá rizika a dopady na pohybový systém při aplikaci daného zatížení. Byl jsem poučen o právu odmítnout účast ve výzkumném projektu nebo svůj souhlas kdykoli odvolat bez represí**, a to písemně Etické komisi UK FTVS, která bude následně informovat předkladatele projektu. Dále potvrzuji, že mi byl předán jeden originál vyhotovení tohoto informovaného souhlasu.

V Praze, dne ....

Jméno a příjmení účastníka: .... Podpis: ....

Appendix 3: Informed consent form – English

INFORMED CONSENT

Dear Sir,

in accordance with the Universal Declaration of Human Rights, European Union Regulation No. 2016/679, and Act No. 110/2019 Coll. - on the processing of personal data, and other generally binding legal regulations (*such as the Helsinki Declaration, adopted by the 18th World Health Assembly in 1964, as amended (Fortaleza, Brazil, 2013); Act on Health Services and the Conditions of their Provision (in particular, the provisions of Section 28 (1) of Act No. 372/2011 Coll.) and the Convention on Human Rights and Biomedicine No. 96/2001, if applicable*), I request your consent to participate in a research project at Charles University, Faculty of Physical Education and Sport, entitled: " Effect of rest duration in explosive strength training of lower extremities ", conducted at the Department of Physiology and Biochemistry.

Project Description: The project will take place from September 2021 to September 2023. The project is being conducted without financial support. The aim of the project is to quantify the effect of different rest lengths on kinetic parameters of jump and fatigue in lower limb explosive strength training. You will participate in measurements of body height, body weight, and body composition using bioelectrical impedance analysis. Subsequently, maximal squat jump, countermovement jump, drop jump from a 32 cm height, and one-repetition maximum squat test with a barbell on the back will be performed. Further data collection will take place in two phases.

The first phase includes a test of 50 repeated jumps with different rest times in random order (0 seconds continuously, 0, 4, 8, and 12 seconds intermittently), 30 repeated jumps onto a 50 cm high box, and 30 repeated jumps over a 50 cm high hurdle with a 10-second rest interval. Additionally, heart rate, blood lactate concentration, and muscle contraction velocity will be measured. Heart rate will be measured non-invasively using a chest strap before, during, and 0, 5, 10, and 15 minutes after the series of repeated jumps. Blood lactate concentration will be measured invasively from a fingertip capillary blood drop by a qualified healthcare professional before, 0, and 15 minutes after the series of repeated jumps. All samples will be collected using standard procedures for biological sample collection. Blood sampling will be performed by a qualified healthcare professional.

Muscle contraction velocity will be measured non-invasively using a TMG device, which stimulates the outer head of the quadriceps muscle on the dominant lower limb and records the muscle reaction velocity. Muscle contraction velocity will be measured by a trained laboratory worker before and 0, 5, 10, and 15 minutes after the series of repeated jumps. Testing will be conducted under standard safety conditions and supervised by the principal investigator and laboratory staff.

The second phase of testing will proceed mostly identically. The only difference will be the performance of all jumps with a weighted vest weighing 10% of your body weight.

Each phase of testing will last approximately 60 minutes and will take place on separate testing days. A minimum rest period of 48 hours will be observed between individual testing days.

The risks associated with data collection are proportional to the nature of the physical activities included in this research. The tests used may cause discomfort in the form of lower limb muscle fatigue. Possible risks to joint structures and the spine are mitigated by the relatively low intensity and volume used in this research compared to the total volume of a typical training unit. The risk of muscle injuries such as muscle strain, lower limb joint injury will be reduced by thorough warm-up before each data collection.

A prerequisite for your participation in the research is a valid medical examination by a sports physician and previous experience with strength training, as well as experience with this type of load and exercise. If you participate in the second part of data collection, you must have experience with weighted jump training. You cannot participate in the project if you are unable to perform a maximum vertical jump or squat with a barbell on your shoulders without pain. Another contraindication is the inability to squat to a depth where the thigh bone is in a horizontal position or if you are currently undergoing rehabilitation after an injury or surgery. Individuals with acute (especially infectious), asthmatic, and cardiovascular diseases with any musculoskeletal condition or limitation and in convalescence after illness or injury will not participate in the testing.

The expected benefit of the research project lies in improving the training process of explosive strength of the lower limbs. The results of this research will provide important information regarding the minimization of fatigue in training practice, leading to increased effectiveness and safety of lower limb explosive strength training.

Participants will not receive any financial or other rewards for participating in the research project.

You will be able to familiarize yourself with the overall results and conclusions of the research project in the dissertation at the UK Digital Repository or via email at: tino@tinojanikov.com

Protection of Personal Data: Data will be collected and processed in accordance with the rules defined by European Union Regulation No. 2016/679 and Act No. 110/2019 Coll. - on the processing of personal data. The following personal data will be obtained: age, body height, body weight, parameters of body composition in the form of bioelectrical impedance analysis results, lengths of body segments, results of movement tests described above in more detail. Data will be securely stored on a password-protected computer. Access to the data will be granted to the project proposer.

I understand that the text is anonymized unless it contains any information that may individually or collectively lead to the identification of a specific person - I will ensure that individuals are not identifiable in the text of the work. Personal data that could lead to the identification of research participants will be anonymized using numerical codes within 1 day after testing.

The obtained data will be processed, securely stored, and published in an anonymous form in the dissertation of the proposer, in scientific journals, or in data repositories, monographs, and presented at conferences, or may be used for further research at the UK Faculty of Physical Education and Sport.

Taking photographs/videos/audio recordings of participants: No photographs, audio recordings, or video recordings will be taken during the research.

To the fullest extent possible, I will ensure that the obtained data are not misused.

Name and surname of the proposer and principal investigator of the project:

Mgr. M. Tino Janikov

Name and surname of the person who provided the instructions:

Mgr. M. Tino Janikov Signature: ………………

I declare and confirm by my own handwritten signature below that I voluntarily consent to participate in the above-mentioned project and that I have had the opportunity to thoroughly consider all relevant information about the research, ask about everything relevant to participation in the research, and have received clear and understandable answers to my questions. **I confirm that I have a valid medical examination by a sports physician. I am aware of the demanding nature of strength training and the associated risks. All risks and impacts on the musculoskeletal system of the applied load have been thoroughly explained to me. I have been informed of the right to refuse participation in the research project or to revoke my consent at any time without repercussions**, in writing to the Ethics Committee of the UK Faculty of Physical Education and Sport, who will subsequently inform the project proposer. Furthermore, I confirm that one original copy of this informed consent has been provided to me.

In Prague, on [date] ……………………

Participant's full name ……………………………… Signature: ………………………

Appendix 4: Correlation tests results – the first data collection

			Body Height	Body Weight	Body Fat	Leg Length	Upper Leg Length	Lower Leg Length
CMD	**BJ**	**r/r_s**	−0.13	−0.34	−0.10	0.14	0.01	0.17
		p	0.586	0.148	0.661	0.560	0.955	0.468
	CMJ	**r/r_s**	−0.09	−0.30	−0.05	0.20	−0.03	0.33
		p	0.705	0.206	0.841	0.389	0.899	0.161
	HJ	**r/r_s**	0.02	−0.13	−0.20	−0.02	−0.03	0.02
		p	0.922	0.575	0.410	0.935	0.891	0.930
IF-r relative to BW	**BJ**	**r/r_s**	−0.19	0.05	−0.04	0.05	−0.05	0.02
		p	0.420	0.821	0.880	0.826	0.826	0.930
	CMJ	**r/r_s**	0.04	−0.20	−0.42	0.34	0.37	−0.03
		p	0.852	0.409	0.066	0.148	0.112	0.905
	HJ	**r/r_s**	−0.03	−0.22	−0.35	0.39	0.03	0.38
		p	0.909	0.342	0.128	0.092	0.900	0.102
IF-v relative to BW	**BJ**	**r/r_s**	−0.18	0.06	−0.03	0.06	−0.05	0.03
		p	0.441	0.796	0.895	0.791	0.845	0.895
	CMJ	**r/r_s**	0.00	−0.15	−0.39	0.33	0.39	−0.05
		p	0.992	0.540	0.086	0.150	0.092	0.840
	HJ	**r/r_s**	−0.03	−0.21	−0.35	0.40	0.04	0.38
		p	0.907	0.370	0.133	0.078	0.860	0.098
JH	**BJ**	**r/r_s**	0.00	−0.18	−0.17	0.15	−0.17	**0.46**
		p	0.972	0.444	0.484	0.518	0.481	**0.043**
	CMJ	**r/r_s**	−0.05	−0.18	0.06	0.15	−0.21	**0.52**
		p	0.823	0.446	0.808	0.535	0.364	**0.019**
	HJ	**r/r_s**	0.06	−0.24	−0.17	0.07	−0.26	**0.49**
		p	0.801	0.309	0.473	0.758	0.262	**0.029**

Appendix 4: Continued

			Body Height	**Body Weight**	**Body Fat**	**Leg Length**	**Upper Leg Length**	**Lower Leg Length**
MCV	**BJ**	**r/r_s**	−0.29	−0.22	−0.06	−0.25	−0.23	−0.02
		p	0.218	0.346	0.806	0.281	0.334	0.947
	CMJ	**r/r_s**	−0.21	−0.36	−0.29	−0.28	−0.41	0.21
		p	0.365	0.118	0.214	0.230	0.076	0.384
	HJ	**r/r_s**	−0.37	−0.25	−0.13	−0.33	−0.18	−0.13
		p	0.105	0.284	0.574	0.151	0.448	0.574
PCP	**BJ**	**r/r_s**	0.31	**0.59**	0.35	−0.14	−0.25	0.17
		p	0.188	**0.006**	0.128	0.544	0.282	0.471
	CMJ	**r/r_s**	0.07	0.43	0.28	**−0.47**	−0.39	−0.14
		p	0.781	0.060	0.232	**0.038**	0.091	0.548
	HJ	**r/r_s**	0.25	**0.59**	0.42	−0.37	−0.43	0.11
		p	0.297	**0.007**	0.067	0.103	0.061	0.652
PCV	**BJ**	**r/r_s**	−0.03	0.03	0.26	0.00	−0.28	0.39
		p	0.906	0.905	0.268	0.985	0.224	0.086
	CMJ	**r/r_s**	−0.21	−0.24	−0.03	−0.25	**−0.54**	**0.45**
		p	0.383	0.312	0.911	0.298	**0.014**	**0.044**
	HJ	**r/r_s**	−0.20	−0.13	0.07	−0.24	**−0.51**	0.41
		p	0.408	0.577	0.775	0.309	**0.023**	0.072
PF-h relative to BW	**BJ**	**r/r_s**	−0.34	−0.07	0.21	**−0.54**	−0.38	−0.37
		p	0.141	0.782	0.384	**0.013**	0.097	0.104
	CMJ	**r/r_s**	−0.03	0.21	0.00	0.04	0.10	0.02
		p	0.899	0.370	0.990	0.875	0.665	0.920
	HJ	**r/r_s**	−0.42	−0.16	0.27	**−0.47**	**−0.62**	0.08
		p	0.063	0.490	0.243	**0.036**	**0.003**	0.734

Appendix 4: Continued

			Body Height	**Body Weight**	**Body Fat**	**Leg Length**	**Upper Leg Length**	**Lower Leg Length**
PF-r relative to BW	**BJ**	**r/r$_s$**	0.03	0.01	−0.40	−0.21	−0.03	−0.24
		p	0.910	0.952	0.079	0.377	0.892	0.306
	CMJ	**r/r$_s$**	−0.13	−0.18	**−0.46**	−0.33	−0.18	−0.18
		p	0.573	0.439	**0.041**	0.160	0.443	0.435
	HJ	**r/r$_s$**	−0.23	0.09	−0.06	−0.24	−0.06	−0.25
		p	0.329	0.691	0.811	0.307	0.816	0.295
PF-v relative to BW	**BJ**	**r/r$_s$**	0.03	0.04	−0.38	−0.24	−0.06	−0.24
		p	0.905	0.883	0.102	0.309	0.803	0.301
	CMJ	**r/r$_s$**	−0.11	−0.16	**−0.48**	−0.31	−0.14	−0.22
		p	0.631	0.508	**0.030**	0.185	0.550	0.354
	HJ	**r/r$_s$**	−0.23	0.09	−0.06	−0.23	−0.02	−0.27
		p	0.322	0.701	0.791	0.336	0.930	0.243
RFD	**BJ**	**r/r$_s$**	0.31	0.22	−0.11	−0.14	−0.15	0.04
		p	0.180	0.343	0.657	0.568	0.519	0.877
	CMJ	**r/r$_s$**	0.35	0.38	−0.15	−0.41	−0.31	−0.111
		p	0.136	0.097	0.538	0.071	0.179	0.641
	HJ	**r/r$_s$**	0.17	0.34	0.08	−0.18	−0.24	0.11
		p	0.471	0.147	0.734	0.453	0.302	0.643
TIT	**BJ**	**r/r$_s$**	−0.03	−0.12	−0.02	0.26	0.19	0.08
		p	0.903	0.618	0.941	0.261	0.417	0.729
	CMJ	**r/r$_s$**	−0.02	−0.12	0.24	0.28	0.04	0.34
		p	0.935	0.621	0.302	0.228	0.883	0.145
	HJ	**r/r$_s$**	0.24	0.03	0.02	0.05	−0.13	0.26
		p	0.302	0.890	0.932	0.836	0.584	0.269

Appendix 4: Continued

			Body Height	**Body Weight**	**Body Fat**	**Leg Length**	**Upper Leg Length**	**Lower Leg Length**
TTPCP	**BJ**	**r/r_s**	0.03	−0.19	−0.02	0.31	0.01	0.42
		p	0.895	0.424	0.933	0.179	0.976	0.064
	CMJ	**r/r_s**	−0.02	0.05	0.43	0.36	0.12	0.33
		p	0.928	0.845	0.060	0.114	0.610	0.161
	HJ	**r/r_s**	0.31	−0.14	−0.26	0.26	−0.10	**0.49**
		p	0.178	0.557	0.263	0.277	0.687	**0.027**
TTPCV	**BJ**	**r/r_s**	0.09	−0.21	−0.04	0.51	0.23	0.36
		p	0.693	0.367	0.861	0.022	0.321	0.122
	CMJ	**r/r_s**	−0.04	−0.08	0.23	0.40	0.16	0.32
		p	0.880	0.729	0.319	0.079	0.506	0.164
	HJ	**r/r_s**	0.10	−0.28	−0.18	0.28	−0.06	**0.47**
		p	0.665	0.235	0.455	0.235	0.798	**0.035**

BJ = box jump, BW = body weight, CMD = countermovement depth, CMJ = countermovement jump, HJ = hurdle jump, IF-r = peak resultant landing forces, IF-v = peak vertical landing forces, JH = jump height, MCV = mean concentric velocity, p = probability value resulting from correlation test, PCP = peak concentric power, PCV = peak concentric velocity, PF-h = peak horizontal take-off force, PF-r = peak resultant take-off force, PF-v = peak vertical take-off force, r = Pearson's correlation coefficient, r_s = Spearman's correlation coefficient, RFD = average take-off rate of force development, TIT = total impulsion time, TTPCP = time to peak concentric power, TTPCV = time to peak concentric velocity.

Appendix 5: Correlation tests results – the second data collection

		Body Height	Body Weight	Body Fat	Leg Length	Leg Length Discrepancy	Training Experience
ΔCMD	**r/r_s**	0.49	0.13	−0.41	**0.58**	−0.18	−0.32
	p	0.078	0.648	0.144	**0.029**	0.532	0.262
ΔMHD	**r/r_s**	0.02	0.16	0.02	0.16	−0.23	−0.07
	p	0.939	0.573	0.955	0.573	0.439	0.808
ΔJH	**r/r_s**	0.10	0.37	−0.01	0.27	−0.25	−0.05
	p	0.737	0.191	0.982	0.358	0.383	0.875
ΔMCV	**r/r_s**	0.10	0.37	0.16	0.08	−0.27	−0.05
	p	0.737	0.191	0.580	0.794	0.356	0.876
ΔPCV	**r/r_s**	0.05	0.28	0.05	0.22	−0.25	−0.10
	p	0.874	0.329	0.868	0.445	0.396	0.733
ΔTTPCV	**r/r_s**	0.19	−0.15	−0.24	0.36	−0.06	−0.09
	p	0.523	0.605	0.409	0.209	0.836	0.764
ΔMEV	**r/r_s**	−0.31	−0.48	−0.10	−0.39	0.32	−0.08
	p	0.284	0.080	0.739	0.164	0.267	0.798
ΔMinEV	**r/r_s**	−0.21	−0.36	0.01	−0.37	0.34	0.07
	p	0.474	0.209	0.982	0.191	0.231	0.813
ΔBL R-P1	**r/r_s**	0.32	0.38	0.31	0.40	−0.50	0.39
	p	0.263	0.184	0.287	0.157	0.067	0.171
ΔBL P1-P15	**r/r_s**	**−0.56**	−0.11	0.23	−0.36	0.11	0.09
	p	**0.036**	0.703	0.435	0.203	0.714	0.753

Appendix 5: Continued

		Body Height	**Body Weight**	**Body Fat**	**Leg Length**	**Leg Length Discrepancy**	**Training Experience**
ΔHR Pre-P0	**r/r_s**	−0.18	0.36	**0.55**	0.02	−0.40	0.31
	p	0.539	0.204	**0.043**	0.946	0.160	0.280
HR P0	**r/r_s**	−0.35	−0.24	0.31	−0.25	−0.25	0.19
	p	0.226	0.416	0.282	0.390	0.390	0.526
ΔHR P0-P5	**r/r_s**	−0.03	0.05	0.16	0.20	0.08	0.26
	p	0.929	0.869	0.588	0,487	0.798	0.366
ΔTMG-Dm R-P1	**r/r_s**	0.22	0.16	0.17	0.22	−0.34	0.19
	p	0.448	0.594	0.559	0.459	0.237	0.657
ΔTMG-Dm P1-P5	**r/r_s**	0.07	−0.20	−0.17	0.20	−0.07	0.20
	p	0.812	0.493	0.565	0.493	0.811	0.498
ΔTMG-Dm P1-P10	**r/r_s**	−0.13	−0.16	−0.16	0.06	0.09	0.07
	p	0.660	0.578	0.583	0.840	0.762	0.824
ΔTMG-Dm P1-P15	**r/r_s**	−0.34	−0.29	−0.33	−0.06	0.32	−0.38
	p	0.231	0.314	0.244	0.840	0.259	0.183
ΔTMG-Dm P5-P10	**r/r_s**	−0.07	0.06	0.05	−0.05	0.12	−0.11
	p	0.805	0.840	0.870	0.870	0.678	0.707
ΔTMG-Dm P5-P15	**r/r_s**	−0.34	−0.09	−0.17	−0.33	0.38	−0.45
	p	0.235	0.759	0.552	0.253	0.175	0.102
ΔTMG-Dm P10-P15	**r/r_s**	−0.07	0.04	−0.01	−0.43	0.44	−0.29
	p	0.823	0.881	0.976	0.128	0.117	0.316

Appendix 5: Continued

		Body Height	**Body Weight**	**Body Fat**	**Leg Length**	**Leg Length Discrepancy**	**Training Experience**
ΔTMG-Tc R-P1	**r/r_s**	−0.16	−0.27	0.1	0.17	−0.06	0.24
	p	0.594	0.358	0.725	0.563	0.849	0.403
ΔTMG-Tc P1-P5	**r/r_s**	0.15	0.37	0.01	−0.07	−0.12	−0.16
	p	0.604	0.197	0.962	0.817	0.690	0.591
ΔTMG-Tc P1-P10	**r/r_s**	0.35	0.38	0.11	−0.16	−0.03	−0.07
	p	0.227	0.180	0.714	0.573	0.911	0.805
ΔTMG-Tc P1-P15	**r/r_s**	0.22	0.17	−0.20	−0.18	0.16	−0.37
	p	0.446	0.553	0.483	0.533	0.575	0.192
ΔTMG-Tc P5-P10	**r/r_s**	0.45	**0.56**	0.23	−0.08	−0.10	0.10
	p	0.107	**0.039**	0.433	0.782	0.738	0.733
ΔTMG-Tc P5-P15	**r/r_s**	0.24	0.23	−0.14	−0.26	0.31	−0.47
	p	0.409	0.436	0.637	0.375	0.282	0.094
ΔTMG-Tc P10-P15	**r/r_s**	0.04	−0.03	−0.23	−0.19	0.26	−0.45
	p	0.899	0.923	0.427	0.523	0.365	0.107
RPE	**r/r_s**	**−0.55**	**−0.63**	0.17	−0.30	0.01	0.30
	p	**0.040**	**0.017**	0.570	0.289	0.966	0.298

BL = blood lactate concentration, CMD = countermovement depth, HR = heart rate, JH = jump height, MCV = mean concentric velocity, MEV = mean eccentric velocity, MHD = maximal horizontal displacement, MinEV = minimal eccentric velocity, NA = not applicable, p = probability value resulting from correlation test, P0–P15 = measurement 0–15 min. after the last intervention jump, Pre = measurement 1 second before the first jump, PCV = peak concentric velocity, R = resting value, r = Pearson's correlation coefficient, r_s = Spearman's correlation coefficient, RPE = rating of perceived exertion, TMG-Dm = maximal muscle belly displacement of m. vastus lateralis measured via tensiomyography, TMG-Tc = contraction time of m. vastus lateralis measured via tensiomyography, TTPCV = time to peak concentric velocity.

Appendix 6: Correlation tests results – the second data collection

		Squat Jump	**CMJ**	**Drop Jump**	**Absolute Back Squat 1RM**	**Relative Back Squat 1RM**	**Back Squat LVP Slope**
ΔCMD	**r/r$_s$**	−0.25	−0.29	−0.12	**−0.58**	**−0.67**	−0.25
	p	0.391	0.318	0.692	**0.031**	**0.008**	0.392
ΔMHD	**r/r$_s$**	−0.48	-0.51	−0.35	-0.16	−0.28	0.31
	p	0.079	0.060	0.224	0.586	0.330	0.274
ΔJH	**r/r$_s$**	−0.46	−0.49	−0.51	−0.18	−0.46	0.08
	p	0.100	0.078	0.061	0.530	0.098	0.794
ΔMCV	**r/r$_s$**	**−0.72**	−0.43	−0.42	0.03	−0.30	0.28
	p	**0.004**	0.121	0.136	0.921	0.302	0.333
ΔPCV	**r/r$_s$**	**−0.57**	−0.48	−0.50	−0.09	−0.33	0.09
	p	**0.034**	0.083	0.066	0.748	0.246	0.751
ΔTTPCV	**r/r$_s$**	0.40	0.21	0.15	−0.12	0.03	−0.26
	p	0.156	0.464	0.605	0.690	0.911	0.366
ΔMEV	**r/r$_s$**	**0.56**	0.39	0.27	0.08	0.53	−0.18
	p	**0.036**	0.166	0.345	0.785	0.052	0.539
ΔMinEV	**r/r$_s$**	**0.61**	0.46	0.44	0.25	0.52	−0.02
	p	**0.020**	0.099	0.114	0.392	0.054	0.942
ΔBL R-P1	**r/r$_s$**	−0.12	−0.48	−0.43	0.14	−0.18	0.33
	p	0.671	0.084	0.121	0.624	0.541	0.250
ΔBL P1-P15	**r/r$_s$**	0.37	0.42	**0.63**	0.44	0.48	0.16
	p	0.193	0.132	**0.016**	0.120	0.081	0.592

Appendix 6: Continued

		Squat Jump	**CMJ**	**Drop Jump**	**Absolute Back Squat 1RM**	**Relative Back Squat 1RM**	**Back Squat LVP Slope**
ΔHR Pre-P0	**r/r_s**	**−0.80**	−0.45	−0.35	0.39	0.06	**0.65**
	p	**0.001**	0.105	0.223	0.169	0.848	**0.011**
HR P0	**r/r_s**	0.07	0.19	0.14	0.43	0.46	0.28
	p	0.816	0.524	0.621	0.127	0.102	0.325
ΔHR P0-P5	**r/r_s**	0.38	0.27	0.42	0.13	0.14	−0.08
	p	0.178	0.349	0.132	0.664	0.625	0.776
ΔTMG-Dm R-P1	**r/r_s**	−0.40	−0.47	−0.48	0.03	0.01	0.06
	p	0.162	0.091	0.082	0.917	0.969	0.840
ΔTMG-Dm P1-P5	**r/r_s**	0.01	0.33	0.27	−0.10	0.11	−0.26
	p	0.964	0.254	0.701	0.728	0.716	0.368
ΔTMG-Dm P1-P10	**r/r_s**	**0.54**	0.53	0.38	−0.06	0.09	−0.36
	p	**0.045**	0.051	0.183	0.826	0.754	0.212
ΔTMG-Dm P1-P15	**r/r_s**	0.31	0.39	0.33	−0.25	0.01	−0.18
	p	0.282	0.167	0.254	0.384	0.977	0.537
ΔTMG-Dm P5-P10	**r/r_s**	0.43	0.33	0.21	−0.01	−0.05	−0.20
	p	0.123	0.249	0.473	0.964	0.870	0.497
ΔTMG-Dm P5-P15	**r/r_s**	0.17	0.12	0.10	−0.15	−0.06	0.02
	p	0.557	0.689	0.733	0.613	0.828	0.950
ΔTMG-Dm P10-P15	**r/r_s**	−0.03	0.06	0.24	0.10	0.05	0.31
	p	0.917	0.852	0.409	0.740	0.864	0.288

Appendix 6: Continued

		Squat Jump	**CMJ**	**Drop Jump**	**Absolute Back Squat 1RM**	**Relative Back Squat 1RM**	**Back Squat LVP Slope**
ΔTMG-Tc R-P1	**r/r$_s$**	−0.01	0.11	0.27	0.04	0.27	−0.06
	p	0.970	0.714	0.358	0.887	0.358	0.84
ΔTMG-Tc P1-P5	**r/r$_s$**	−0.05	0.00	−0.17	0.11	−0.22	−0.03
	p	0.875	0.998	0.568	0.718	0.443	0.926
ΔTMG-Tc P1-P10	**r/r$_s$**	0.03	−0.02	−0.15	0.08	−0.19	0.09
	p	0.929	0.958	0.605	0.775	0.523	0.759
ΔTMG-Tc P1-P15	**r/r$_s$**	−0.19	−0.24	−0.38	−0.27	−0.40	−0.05
	p	0.507	0.409	0.180	0.347	0.154	0.876
ΔTMG-Tc P5-P10	**r/r$_s$**	−0.15	−0.04	−0.15	0.33	−0.20	0.23
	p	0.620	0.879	0.609	0.253	0.502	0.438
ΔTMG-Tc P5-P15	**r/r$_s$**	−0.31	−0.02	−0.08	−0.12	−0.28	0.16
	p	0.284	0.958	0.794	0.695	0.334	0.573
ΔTMG-Tc P10-P15	**r/r$_s$**	−0.41	−0.23	−0.39	−0.29	−0.23	−0.02
	p	0.146	0.436	0.164	0.307	0.436	0.935
RPE	**r/r$_s$**	0.14	0.23	0.19	0.23	**0.72**	−0.07
	p	0.640	0.420	0.505	0.424	**0.003**	0.805

BL = blood lactate concentration, CMD = countermovement depth, CMJ = countermovement jump, HR = heart rate, JH = jump height, LVP = load-velocity profile, MCV = mean concentric velocity, MEV = mean eccentric velocity, MHD = maximal horizontal displacement, MinEV = minimal eccentric velocity, p = probability value resulting from correlation test, P0–P15 = measurement 0–15 min. after the last intervention jump, Pre = measurement 1 second before the first jump, PCV = peak concentric velocity, R = resting value, r = Pearson's correlation coefficient, r_s *= Spearman's correlation coefficient, RPE = rating of perceived exertion, TMG-Dm = maximal muscle belly displacement of m. vastus lateralis measured via tensiomyography, TMG-Tc = contraction time of m. vastus lateralis measured via tensiomyography, TTPCV = time to peak concentric velocity.*

Appendix 7: Results of between and within relative strength level subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Strength	Lower Strength				Higher Strength			Lower Strength		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.649 ± 0.074	0.612 ± 0.057	0.52	−0.69	1.73	–	–	–	–	–	–
	G10	0.668 ± 0.114	0.753 ± 0.118 ‡	0.67	−0.55	1.89	–	–	–	–	–	–
	G1-G10	0.019 ± 0.056	0.140 ± 0.103 *	1.36	0.04	2.68	0.18	−1.01	1.37	1.40	0.08	2.73
Maximal horizontal displacement	G1	0.118 ± 0.043	0.093 ± 0.022	0.67	−0.55	1.89	–	–	–	–	–	–
	G10	0.099 ± 0.030	0.117 ± 0.026	0.58	−0.64	1.79	–	–	–	–	–	–
	G1-G10	−0.019 ± 0.053	0.023 ± 0.046	0.80	−0.44	2.03	0.48	−0.73	1.68	0.88	−0.36	2.12
Jump height	G1	0.400 ± 0.037	0.372 ± 0.064	0.49	−0.72	1.69	–	–	–	–	–	–
	G10	0.171 ± 0.060 ‡	0.213 ± 0.049	0.70	−0.53	1.92	–	–	–	–	–	–
	G1-G10	−0.228 ± 0.088	−0.159 ± 0.063	0.83	−0.40	2.07	4.20	2.07	6.33	2.58	0.98	4.19
Mean concentric velocity	G1	2.049 ± 0.036	1.891 ± 0.294	0.70	−0.53	1.92	–	–	–	–	–	–
	G10	1.381 ± 0.387 ‡	1.585 ± 0.103 ‡	0.67	−0.55	1.89	–	–	–	–	–	–
	G1-G10	−0.669 ± 0.362	−0.306 ± 0.264	1.06	−0.21	2.33	2.25	0.73	3.77	1.28	−0.02	2.58
Peak concentric velocity	G1	3.364 ± 0.179	3.157 ± 0.368	0.66	−0.56	1.88	–	–	–	–	–	–
	G10	2.181 ± 0.483 ‡	2.518 ± 0.348 ‡	0.74	−0.49	1.96	–	–	–	–	–	–
	G1-G10	−1.183 ± 0.516	−0.640 ± 0.276	1.21	−0.08	2.50	3.00	1.27	4.73	1.65	0.27	3.02
Time to peak concentric velocity	G1	0.284 ± 0.037	0.287 ± 0.037	0.06	−1.13	1.25	–	–	–	–	–	–
	G10	0.510 ± 0.274	0.386 ± 0.071 ‡	0.57	−0.64	1.78	–	–	–	–	–	–
	G1-G10	0.226 ± 0.242	0.100 ± 0.080	0.65	−0.57	1.87	1.07	−0.20	2.34	1.62	0.25	2.99

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher strength subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 7: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Strength	Lower Strength				Higher Strength			Lower Strength		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.919 ± 0.107	−1.661 ± 0.199 *	1.49	0.15	2.81	–	–	–	–	–	–
	G10	−1.478 ± 0.271 ‡	−1.718 ± 0.184	0.95	−0.30	2.21	–	–	–	–	–	–
	G1-G10	0.441 ± 0.238	−0.056 ± 0.278 *	1.78	0.37	3.18	1.97	0.53	3.42	0.27	−0.92	1.46
Minimal eccentric velocity	G1	−3.246 ± 0.163	−2.905 ± 0.190 *	1.63	0.26	3.00	–	–	–	–	–	–
	G10	−2.281 ± 0.349 ‡	−2.683 ± 0.228 *	1.26	−0.04	2.56	–	–	–	–	–	–
	G1-G10	0.965 ± 0.432	0.223 ± 0.243 *	1.95	0.51	3.40	3.27	1.45	5.08	0.92	−0.33	2.17
RPE	P0	9.833 ± 0.408	8.333 ± 1.211 *	1.53	0.18	2.88	–	–	–	–	–	–
Blood lactate concentration	R	1.817 ± 0.349	1.733 ± 0.596	0.16	−1.03	1.35	–	–	–	–	–	–
	P1	10.500 ± 3.097 †	10.400 ± 1.973 †	0.04	−1.15	1.22	–	–	–	–	–	–
	P15	12.950 ± 4.023 †	10.533 ± 3.486 †	0.59	−0.62	1.81	–	–	–	–	–	–
	R-P1	8.683 ± 3.041	8.667 ± 2.298	0.01	−1.18	1.19	3.64	1.70	5.57	5.49	2.90	8.08
	P1-P15	2.450 ± 4.668	0.133 ± 3.634	0.51	−0.70	1.72	0.63	−0.59	1.85	0.04	−1.14	1.23
Heart rate	PRE	123.67 ± 18.57	117.00 ± 20.19	0.32	−0.88	1.51	–	–	–	–	–	–
	P0	181.33 ± 14.38 †	178.50 ± 7.26 †	0.23	−0.96	1.42	–	–	–	–	–	–
	P5	105.67 ± 13.19 ¥	94.17 ± 13.67 †¥	0.79	−0.44	2.02	–	–	–	–	–	–
	PRE-P0	57.67 ± 18.74	61.50 ± 20.01	0.18	−1.01	1.37	3.21	1.41	5.00	3.74	1.77	5.71
	P0-P5	−75.67 ± 7.97	−84.33 ± 11.62	0.80	−0.43	2.04	5.06	2.63	7.50	7.11	3.90	10.32

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher strength subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 7: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Strength	Lower Strength				Higher Strength			Lower Strength		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.763 ± 2.181	5.647 ± 1.417	0.06	−1.13	1.25	–	–	–	–	–	–
	P1	3.990 ± 1.878	3.413 ± 2.150	0.26	−0.93	1.46	–	–	–	–	–	–
	P5	5.005 ± 2.679	4.263 ± 2.193	0.28	−0.91	1.47	–	–	–	–	–	–
	P10	4.885 ± 2.410	4.223 ± 1.840	0.28	−0.91	1.48	–	–	–	–	–	–
	P15	4.792 ± 2.132	4.483 ± 1.859	0.14	−1.05	1.33	–	–	–	–	–	–
	R-P1	−1.773 ± 1.284	−2.233 ± 2.189	0.24	−0.96	1.43	0.80	−0.43	2.04	1.13	−0.15	2.41
	P1-P5	1.015 ± 0.833	0.850 ± 0.605	0.21	−0.98	1.40	0.40	−0.79	1.60	0.36	−0.84	1.56
	P1-P10	0.895 ± 0.785	0.810 ± 0.568	0.11	−1.07	1.30	0.38	−0.82	1.58	0.37	−0.82	1.57
	P1-P15	0.802 ± 0.595	1.070 ± 1.193	0.26	−0.93	1.46	0.37	−0.83	1.57	0.49	−0.71	1.70
	P5-P10	−0.120 ± 0.662	−0.040 ± 0.531	0.12	1.07	1.31	0.04	−1.14	1.23	0.02	−1.17	1.21
	P5-P15	−0.213 ± 0.887	0.220 ± 1.274	0.36	−0.83	1.56	0.08	−1.11	1.27	0.10	−1.09	1.29
	P10-P15	−0.093 ± 0.440	0.260 ± 1.161	0.37	−0.83	1.57	0.04	−1.15	1.23	0.13	−1.06	1.32

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher strength subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 7: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Strength	Lower Strength				Higher Strength			Lower Strength		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	24.847 ± 6.503	30.068 ± 6.771	0.73	−0.50	1.96	–	–	–	–	–	–
	P1	25.833 ± 8.378	27.822 ± 7.996	0.22	−0.97	1.42	–	–	–	–	–	–
	P5	21.862 ± 6.609	25.63 ± 6.096	0.55	−0.66	1.76	–	–	–	–	–	–
	P10	22.593 ± 6.667	26.512 ± 7.174	0.52	−0.69	1.73	–	–	–	–	–	–
	P15	22.988 ± 6.034	28.945 ± 7.171	0.83	−0.41	2.07	–	–	–	–	–	–
	R-P1	0.987 ± 2.055	−2.247 ± 4.250	0.89	−0.35	2.14	0.12	−1.07	1.31	0.28	−0.91	1.47
	P1-P5	−3.972 ± 2.463	−2.192 ± 3.357	0.56	−0.65	1.77	0.49	−0.72	1.69	0.28	−0.91	1.48
	P1-P10	−3.240 ± 2.425	−1.31 ± 4.442	0.50	−0.71	1.70	0.40	−0.80	1.59	0.16	−1.03	1.35
	P1-P15	−2.845 ± 3.337	1.123 ± 4.159	0.97	−0.28	2.23	0.36	−0.84	1.56	0.14	−1.05	1.33
	P5-P10	0.732 ± 0.843	0.882 ± 1.763	0.10	−1.09	1.29	0.10	−1.09	1.29	0.12	−1.07	1.31
	P5-P15	1.127 ± 1.207	3.315 ± 3.133	0.85	−0.39	2.09	0.16	−1.03	1.35	0.46	−0.74	1.66
	P10-P15	0.395 ± 1.360	2.433 ± 3.359	0.73	−0.49	1.96	0.06	−1.13	1.25	0.31	−0.88	1.51

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher strength subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 8: Results of between and within load-velocity profile slope steepness subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Steepness	Lower Steepness				Higher Steepness			Lower Steepness		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.610 ± 0.063	0.623 ± 0.038	0.23	−0.96	1.43	–	–	–	–	–	–
	G10	0.674 ± 0.089	0.700 ± 0.143	0.20	−0.99	1.39	–	–	–	–	–	–
	G1-G10	0.064 ± 0.039	0.077 ± 0.150	0.11	−1.08	1.30	0.77	−0.46	2.00	0.68	−0.54	1.90
Maximal horizontal displacement	G1	0.094 ± 0.020	0.124 ± 0.047	0.75	−0.48	1.98	–	–	–	–	–	–
	G10	0.104 ± 0.035	0.128 ± 0.029	0.69	−0.53	1.91	–	–	–	–	–	–
	G1-G10	0.009 ± 0.044	0.004 ± 0.066	0.09	−1.10	1.28	0.31	−0.89	1.50	0.09	−1.1	1.28
Jump height	G1	0.381 ± 0.068	0.388 ± 0.034	0.13	−1.06	1.32	–	–	–	–	–	–
	G10	0.209 ± 0.038 ‡	0.214 ± 0.052 ‡	0.10	−1.09	1.29	–	–	–	–	–	–
	G1-G10	−0.172 ± 0.076	−0.175 ± 0.069	0.03	−1.15	1.22	2.89	1.19	4.59	3.66	1.72	5.60
Mean concentric velocity	G1	1.935 ± 0.294	1.961 ± 0.139	0.11	−1.08	1.30	–	–	–	–	–	–
	G10	1.546 ± 0.079 ‡	1.636 ± 0.178 ‡	0.60	−0.61	1.81	–	–	–	–	–	–
	G1-G10	−0.389 ± 0.293	−0.326 ± 0.16	0.25	−0.95	1.44	1.66	0.29	3.04	1.88	0.45	3.30
Peak concentric velocity	G1	3.220 ± 0.352	3.262 ± 0.257	0.12	−1.06	1.31	–	–	–	–	–	–
	G10	2.487 ± 0.194 ‡	2.521 ± 0.352 ‡	0.11	−1.08	1.30	–	–	–	–	–	–
	G1-G10	−0.733 ± 0.321	−0.741 ± 0.345	0.02	−1.17	1.21	2.38	0.83	3.93	2.22	0.71	3.73
Time to peak concentric velocity	G1	0.282 ± 0.038	0.287 ± 0.044	0.10	−1.08	1.29	–	–	–	–	–	–
	G10	0.376 ± 0.074 ‡	0.359 ± 0.055 ‡	0.24	−0.95	1.43	–	–	–	–	–	–
	G1-G10	0.094 ± 0.076	0.072 ± 0.048	0.31	−0.89	1.50	1.47	0.13	2.81	1.34	0.03	2.66

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher steepness subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 8: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Steepness	Lower Steepness				Higher Steepness			Lower Steepness		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.702 ± 0.212	−1.796 ± 0.211	0.41	−0.79	1.61	–	–	–	–	–	–
	G10	−1.606 ± 0.137	−1.690 ± 0.229	0.41	−0.79	1.61	–	–	–	–	–	–
	G1-G10	0.096 ± 0.249	0.105 ± 0.317	0.03	−1.16	1.22	0.50	−0.71	1.7	0.44	−0.76	1.64
Minimal eccentric velocity	G1	−2.934 ± 0.237	−3.127 ± 0.207	0.80	−0.43	2.03	–	–	–	–	–	–
	G10	−2.559 ± 0.268 ‡	−2.601 ± 0.171 ‡	0.17	−1.02	1.36	–	–	–	–	–	–
	G1-G10	0.375 ± 0.356	0.526 ± 0.316	0.42	−0.78	1.62	1.37	0.05	2.68	2.56	0.96	4.16
RPE	P0	8.833 ± 1.472	8.667 ± 1.033	0.12	−1.07	1.31	–	–	–	–	–	–
Blood lactate concentration	R	1.917 ± 0.571	1.800 ± 0.303	0.24	−0.95	1.43	–	–	–	–	–	–
	P1	10.333 ± 3.466 †	10.850 ± 1.355 †	0.18	−1.01	1.37	–	–	–	–	–	–
	P15	10.017 ± 2.810 †	12.533 ± 4.246 †	0.65	−0.57	1.86	–	–	–	–	–	–
	R-P1	8.417 ± 3.547	9.050 ± 1.387	0.22	−0.97	1.41	3.13	1.36	4.9	8.51	4.75	12.28
	P1-P15	−0.317 ± 3.370	1.683 ± 4.850	0.44	−0.76	1.64	0.09	−1.10	1.28	0.49	−0.71	1.7
Heart rate	PRE	119.50 ± 20.91	114.17 ± 20.40	0.24	−0.95	1.43	–	–	–	–	–	–
	P0	175.67 ± 9.69 †	180.67 ± 17.28 †	0.33	−0.87	1.52	–	–	–	–	–	–
	P5	95.50 ± 10.11 †¥	96.00 ± 21.58 ¥	0.03	−1.16	1.21	–	–	–	–	–	–
	PRE-P0	56.17 ± 16.82	66.50 ± 19.73	0.52	−0.69	1.73	3.18	1.39	4.97	3.25	1.44	5.05
	P0-P5	−80.17 ± 7.44	−84.67 ± 15.48	0.34	−0.85	1.54	7.47	4.12	10.83	4	1.94	6.05

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher steepness subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 8: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Steepness	Lower Steepness				Higher Steepness			Lower Steepness		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.900 ± 1.621	4.593 ± 1.910	0.68	−0.54	1.90	–	–	–	–	–	–
	P1	3.818 ± 1.779	3.177 ± 2.570	0.27	−0.92	1.46	–	–	–	–	–	–
	P5	4.875 ± 2.469	3.887 ± 2.741	0.35	−0.85	1.55	–	–	–	–	–	–
	P10	4.893 ± 2.047	3.715 ± 2.469	0.48	−0.72	1.68	–	–	–	–	–	–
	P15	5.093 ± 1.947	3.763 ± 2.186	0.59	−0.62	1.81	–	–	–	–	–	–
	R-P1	−2.082 ± 1.281	−1.417 ± 2.239	0.34	−0.86	1.53	1.13	−0.15	2.41	0.58	−0.63	1.79
	P1-P5	1.057 ± 0.774	0.710 ± 0.624	0.46	−0.75	1.66	0.45	−0.75	1.66	0.25	−0.95	1.44
	P1-P10	1.075 ± 0.701	0.538 ± 0.620	0.75	−0.48	1.98	0.52	−0.69	1.72	0.20	−0.99	1.39
	P1-P15	1.275 ± 0.962	0.587 ± 0.721	0.75	−0.48	1.98	0.63	−0.59	1.85	0.23	−0.96	1.42
	P5-P10	0.018 ± 0.625	−0.172 ± 0.501	0.31	−0.89	1.50	0.01	−1.18	1.19	0.06	−1.13	1.25
	P5-P15	0.218 ± 1.265	−0.123 ± 0.713	0.31	−0.89	1.50	0.09	−1.10	1.28	0.05	−1.14	1.23
	P10-P15	0.200 ± 1.187	0.048 ± 0.364	0.16	−1.03	1.35	0.09	−1.10	1.28	0.02	−1.17	1.21

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher steepness subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 8: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Steepness	Lower Steepness				Higher Steepness			Lower Steepness		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	25.732 ± 2.426	27.662 ± 10.127	0.24	−0.95	1.43	–	–	–	–	–	–
	P1	24.228 ± 4.209	24.088 ± 10.299	0.02	−1.17	1.20	–	–	–	–	–	–
	P5	22.423 ± 2.397 †	22.962 ± 8.887	0.08	−1.11	1.26	–	–	–	–	–	–
	P10	22.748 ± 2.430	24.793 ± 9.839	0.26	−0.93	1.46	–	–	–	–	–	–
	P15	24.815 ± 2.216	26.300 ± 10.722	0.18	−1.01	1.37	–	–	–	–	–	–
	R-P1	-1.503 ± 3.633	−3.573 ± 6.785	0.35	−0.85	1.55	0.40	−0.80	1.60	0.32	−0.87	1.52
	P1-P5	-1.805 ± 3.141	−1.127 ± 3.915	0.18	−1.01	1.37	0.49	−0.72	1.69	0.11	−1.08	1.30
	P1-P10	−1.480 ± 4.328	0.705 ± 5.457	0.41	−0.79	1.61	0.40	−0.80	1.60	0.06	−1.12	1.25
	P1-P15	0.587 ± 3.378	2.212 ± 6.564	0.29	−0.91	1.48	0.16	−1.03	1.35	0.19	−1.00	1.38
	P5-P10	0.325 ± 1.521	1.832 ± 1.899	0.81	−0.43	2.04	0.12	−1.06	1.31	0.18	−1.01	1.37
	P5-P15	2.392 ± 2.447	3.338 ± 3.364	0.30	−0.90	1.49	0.96	−0.30	2.21	0.31	−0.88	1.51
	P10-P15	2.067 ± 3.067	1.507 ± 1.912	0.20	−0.99	1.39	0.82	−0.42	2.06	0.14	−1.05	1.32

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher steepness subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 9: Results of between and within squat jump performance subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.661 ± 0.059	0.618 ± 0.067	0.63	−0.59	1.84	–	–	–	–	–	–
	G10	0.689 ± 0.107	0.741 ± 0.125	0.40	−0.80	1.60	–	–	–	–	–	–
	G1-G10	0.028 ± 0.061	0.122 ± 0.120	0.91	−0.33	2.16	0.30	−0.89	1.50	1.12	−0.16	2.40
Maximal horizontal displacement	G1	0.138 ± 0.035	0.089 ± 0.018 *	1.59	0.23	2.95	–	–	–	–	–	–
	G10	0.118 ± 0.030	0.122 ± 0.028 ‡	0.14	−1.05	1.33	–	–	–	–	–	–
	G1-G10	−0.020 ± 0.052	0.033 ± 0.043	1.01	−0.25	2.28	0.56	−0.65	1.77	1.30	0.00	2.61
Jump height	G1	0.414 ± 0.033	0.351 ± 0.045 *	1.46	0.12	2.80	–	–	–	–	–	–
	G10	0.207 ± 0.049 ‡	0.191 ± 0.067 ‡	0.25	−0.94	1.45	–	–	–	–	–	–
	G1-G10	−0.206 ± 0.064	−0.160 ± 0.087	0.56	−0.65	1.77	4.55	2.30	6.80	2.59	0.98	4.21
Mean concentric velocity	G1	2.041 ± 0.164	1.846 ± 0.234	0.89	0.35	2.14	–	–	–	–	–	–
	G10	1.456 ± 0.266 ‡	1.538 ± 0.337	0.25	−0.94	1.44	–	–	–	–	–	–
	G1-G10	−0.585 ± 0.290	−0.308 ± 0.396	0.74	−0.49	1.96	2.44	0.87	4.01	0.98	−0.28	2.23
Peak concentric velocity	G1	3.415 ± 0.205	3.049 ± 0.261 *	1.44	0.11	2.77	–	–	–	–	–	–
	G10	2.424 ± 0.407 ‡	2.344 ± 0.516 ‡	0.16	−1.03	1.35	–	–	–	–	–	–
	G1-G10	−0.992 ± 0.464	−0.704 ± 0.514	0.54	−0.67	1.75	2.84	1.16	4.52	1.59	0.23	2.95
Time to peak concentric velocity	G1	0.295 ± 0.044	0.296 ± 0.041	0.02	−1.16	1.21	–	–	–	–	–	–
	G10	0.475 ± 0.223	0.424 ± 0.195	0.22	−0.97	1.41	–	–	–	–	–	–
	G1-G10	0.179 ± 0.214	0.128 ± 0.175	0.24	−0.95	1.44	1.03	−0.23	2.29	0.84	−0.40	2.08

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher jump subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 9: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.795 ± 0.151	−1.733 ± 0.273	0.26	−0.93	1.45	–	–	–	–	–	–
	G10	−1.474 ± 0.226 ‡	−1.710 ± 0.229	0.96	−0.30	2.21	–	–	–	–	–	–
	G1-G10	0.321 ± 0.306	0.023 ± 0.373	0.80	−0.43	2.04	1.54	0.19	2.89	0.09	−1.10	1.27
Minimal eccentric velocity	G1	−3.141 ± 0.243	−3.007 ± 0.287	0.46	−0.74	1.67	–	–	–	–	–	–
	G10	−2.358 ± 0.350 ‡	−2.644 ± 0.305	0.81	−0.43	2.04	–	–	–	–	–	–
	G1-G10	0.784 ± 0.447	0.363 ± 0.516	0.80	0.43	2.04	2.40	0.84	3.96	1.13	0.15	2.41
RPE	P0	8.833 ± 0.983	8.667 ± 1.506	0.12	−1.07	1.31	–	–	–	–	–	–
Blood lactate concentration	R	1.717 ± 0.256	1.783 ± 0.627	0.13	−1.06	1.32	–	–	–	–	–	–
	P1	10.300 ± 1.885 †	10.867 ± 1.417 †	0.31	−0.88	1.51	–	–	–	–	–	–
	P15	12.833 ± 2.338 †	11.583 ± 4.535 †	0.32	−0.88	1.51	–	–	–	–	–	–
	R-P1	8.583 ± 1.800	9.083 ± 1.967	1.54	0.19	2.89	5.89	3.15	8.63	7.65	4.23	11.08
	P1-P15	2.533 ± 2.727	0.717 ± 4.561	0.65	−0.57	1.87	1.10	−0.17	2.38	0.2	−0.99	1.39
Heart rate	PRE	126.83 ± 24.13	107.17 ± 7.11	1.02	−0.24	2.28	–	–	–	–	–	–
	P0	175.67 ± 13.72 †	180.17 ± 11.75 †	0.33	−0.87	1.52	–	–	–	–	–	–
	P5	99.67 ± 17.76 ¥	95.33 ± 14.98 ¥	0.24	−0.95	1.44	–	–	–	–	–	–
	PRE-P0	48.83 ± 14.88	73.00 ± 14.04 *	0.24	−0.95	1.44	2.30	0.77	3.83	6.94	3.79	10.08
	P0-P5	−76.00 ± 13.15	−84.83 ± 12.01	0.45	−0.76	1.65	4.42	2.22	6.62	5.82	3.1	8.53

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher jump subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 9: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.200 ± 1.352	5.088 ± 2.203	0.06	−1.13	1.24	–	–	–	–	–	–
	P1	2.872 ± 1.183 †	3.348 ± 2.352	0.24	−0.96	1.43	–	–	–	–	–	–
	P5	3.573 ± 1.219	4.068 ± 2.632	0.22	−0.97	1.41	–	–	–	–	–	–
	P10	3.795 ± 1.187	3.805 ± 2.285	0.01	−1.18	1.19	–	–	–	–	–	–
	P15	3.838 ± 1.217	4.157 ± 2.258	0.16	−1.03	1.35	–	–	–	–	–	–
	R-P1	−2.328 ± 1.391	−1.740 ± 2.230	0.29	−0.90	1.49	1.69	0.31	3.08	0.70	−0.52	1.93
	P1-P5	0.702 ± 0.344	0.720 ± 0.721	0.03	−1.16	1.22	0.54	−0.67	1.75	0.27	−0.93	1.46
	P1-P10	0.923 ± 0.558	0.457 ± 0.449	0.85	−0.39	2.09	0.72	−0.51	1.94	0.18	−1.01	1.37
	P1-P15	0.967 ± 0.390	0.808 ± 1.268	0.16	−1.03	1.35	0.74	−0.48	1.97	0.32	−0.87	1.52
	P5-P10	0.222 ± 0.357	−0.263 ± 0.488	1.05	−0.22	2.31	0.17	−1.02	1.36	0.10	−1.09	1.29
	P5-P15	0.265 ± 0.345	0.088 ± 1.390	0.16	−1.03	1.35	0.20	−0.99	1.39	0.03	1.15	1.22
	P10-P15	0.043 ± 0.333	0.352 ± 1.135	0.34	−0.86	1.54	0.03	−1.15	1.22	0.14	−1.05	1.33

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 9: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	26.197 ± 4.746	29.020 ± 9.543	0.35	−0.85	1.54	–	–	–	–	–	–
	P1	22.617 ± 5.357	28.38 ± 10.554	0.64	−0.58	1.85	–	–	–	–	–	–
	P5	21.517 ± 2.607	24.987 ± 8.759	0.50	−0.71	1.70	–	–	–	–	–	–
	P10	22.722 ± 3.516	26.042 ± 9.731	0.42	−0.78	1.62	–	–	–	–	–	–
	P15	23.485 ± 4.461	28.273 ± 9.397	0.60	−0.61	1.81	–	–	–	–	–	–
	R-P1	−3.580 ± 7.137	−0.640 ± 3.794	0.47	−0.73	1.68	0.65	−0.57	1.87	0.06	−1.13	1.25
	P1-P5	−1.100 ± 4.618	−3.393 ± 3.467	0.52	−0.69	1.73	0.24	−0.95	1.43	0.32	−0.87	1.52
	P1-P10	0.105 ± 6.260	−2.338 ± 4.467	0.41	−0.79	1.61	0.02	−1.17	1.21	0.21	−0.98	1.40
	P1-P15	0.868 ± 6.911	−0.107 ± 5.596	0.14	−1.05	1.33	0.16	−1.03	1.35	0.01	−1.18	1.20
	P5-P10	1.205 ± 1.962	1.055 ± 1.741	0.07	−1.11	1.26	0.36	−0.84	1.56	0.11	−1.08	1.29
	P5-P15	1.968 ± 2.908	3.287 ± 3.199	0.40	−0.80	1.60	0.50	−0.71	1.70	0.33	−0.86	1.53
	P10-P15	0.763 ± 1.212	2.232 ± 3.640	0.50	−0.71	1.71	0.18	−1.01	1.37	0.22	−0.98	1.41

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 10: Results of between and within countermovement jump performance subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.638 ± 0.069	0.634 ± 0.074	0.06	−1.13	1.25	–	–	–	–	–	–
	G10	0.665 ± 0.118	0.706 ± 0.091	0.36	−0.84	1.55	–	–	–	–	–	–
	G1-G10	0.027 ± 0.061	0.072 ± 0.080	0.58	−0.63	1.79	0.26	−0.93	1.45	0.80	−0.43	2.04
Maximal horizontal displacement	G1	0.132 ± 0.041	0.097 ± 0.018	1.00	−0.26	2.26	–	–	–	–	–	–
	G10	0.098 ± 0.028	0.128 ± 0.034	0.88	−0.37	2.12	–	–	–	–	–	–
	G1-G10	−0.034 ± 0.039	0.030 ± 0.042 *	1.46	0.13	2.80	0.87	−0.37	2.12	1.04	−0.23	2.30
Jump height	G1	0.422 ± 0.030	0.354 ± 0.046 *	1.60	0.24	2.97	–	–	–	–	–	–
	G10	0.197 ± 0.054 ‡	0.205 ± 0.061 ‡	0.14	−1.05	1.33	–	–	–	–	–	–
	G1-G10	−0.226 ± 0.067	−0.149 ± 0.080	0.96	−0.29	2.22	4.78	2.45	7.11	2.54	0.95	4.14
Mean concentric velocity	G1	2.081 ± 0.118	1.850 ± 0.233	1.16	−0.13	2.44	–	–	–	–	–	–
	G10	1.441 ± 0.264 ‡	1.545 ± 0.337	0.32	−0.88	1.51	–	–	–	–	–	–
	G1-G10	−0.640 ± 0.248	−0.305 ± 0.396	0.93	−0.32	2.19	2.89	1.20	4.59	0.97	−0.28	2.23
Peak concentric velocity	G1	3.467 ± 0.139	3.078 ± 0.255 *	1.75	0.35	3.15	–	–	–	–	–	–
	G10	2.399 ± 0.409 ‡	2.431 ± 0.477 ‡	0.07	−1.12	1.25	–	–	–	–	–	–
	G1-G10	−1.068 ± 0.432	−0.647 ± 0.495	0.84	−0.40	2.08	3.23	1.43	5.03	1.56	0.21	2.92
Time to peak concentric velocity	G1	0.274 ± 0.029	0.308 ± 0.051	0.77	−0.46	2.00	–	–	–	–	–	–
	G10	0.460 ± 0.230	0.430 ± 0.194	0.13	−1.06	1.32	–	–	–	–	–	–
	G1-G10	0.186 ± 0.210	0.121 ± 0.178	0.30	−0.89	1.50	1.04	−0.22	2.31	0.79	−0.44	2.02

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher jump subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 10: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.831 ± 0.079	−1.723 ± 0.281	0.48	−0.72	1.69	–	–	–	–	–	–
	G10	−1.463 ± 0.226 ‡	−1.624 ± 0.188	0.72	−0.51	1.94	–	–	–	–	–	–
	G1-G10	0.368 ± 0.270	0.099 ± 0.301	0.87	−0.37	2.11	2.01	0.55	3.46	0.38	−0.82	1.58
Minimal eccentric velocity	G1	−3.181 ± 0.215	−3.004 ± 0.288	0.64	−0.58	1.86	–	–	–	–	–	–
	G10	−2.341 ± 0.348 ‡	−2.595 ± 0.311 ‡	0.71	−0.51	1.94	–	–	–	–	–	–
	G1-G10	0.840 ± 0.419	0.409 ± 0.509	0.85	−0.39	2.09	2.68	1.05	4.32	1.26	−0.04	2.56
RPE	P0	9.000 ± 1.095	8.667 ± 1.506	0.23	−0.96	1.43	–	–	–	–	–	–
Blood lactate concentration	R	1.683 ± 0.204	1.917 ± 0.588	0.49	−0.72	1.69	–	–	–	–	–	–
	P1	9.383 ± 2.252 †	11.050 ± 1.476 †	0.81	−0.43	2.04	–	–	–	–	–	–
	P15	11.900 ± 3.349 †	11.350 ± 4.421 †	0.13	−1.06	1.32	–	–	–	–	–	–
	R-P1	7.700 ± 2.312	9.133 ± 1.984	0.61	−0.60	1.83	4.44	2.23	6.66	7.50	4.14	10.87
	P1-P15	2.517 ± 2.740	0.300 ± 4.400	0.56	−0.65	1.77	0.81	−0.42	2.05	0.08	−1.10	1.27
Heart rate	PRE	129.00 ± 21.21	105.33 ± 8.45 *	1.35	0.04	2.67	–	–	–	–	–	–
	P0	177.33 ± 10.31 †	173.50 ± 15.22 †	0.27	−0.92	1.47	–	–	–	–	–	–
	P5	99.50 ± 17.93 †¥	91.67 ± 14.22 ¥	0.45	−0.76	1.65	–	–	–	–	–	–
	PRE-P0	48.33 ± 14.68	68.17 ± 14.48	1.26	0.04	2.55	2.68	1.04	4.31	5.11	2.66	7.57
	P0-P5	−77.83 ± 12.21	−81.83 ± 14.29	0.28	−0.92	1.47	4.91	2.53	7.29	5.13	2.67	7.59

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher jump subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 10: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.678 ± 1.316	4.650 ± 2.114	0.54	−0.67	1.75	–	–	–	–	–	–
	P1	3.265 ± 1.883 †	3.722 ± 2.256	0.20	−0.99	1.39	–	–	–	–	–	–
	P5	4.178 ± 2.306	4.243 ± 2.634	0.02	−1.16	1.21	–	–	–	–	–	–
	P10	4.283 ± 1.827	3.998 ± 2.258	0.13	−1.06	1.32	–	–	–	–	–	–
	P15	4.243 ± 1.788	4.390 ± 2.210	0.07	−1.12	1.26	–	–	–	–	–	–
	R-P1	−2.413 ± 1.206	−0.928 ± 1.815	0.89	−0.36	2.13	1.37	0.05	2.69	0.39	−0.81	1.59
	P1-P5	0.913 ± 0.552	0.522 ± 0.525	0.67	−0.55	1.89	0.40	−0.80	1.60	0.20	−1.00	1.39
	P1-P10	1.018 ± 0.410	0.277 ± 0.318 *	1.87	0.44	3.29	0.51	−0.70	1.71	0.11	−1.08	1.30
	P1-P15	0.978 ± 0.372	0.668 ± 1.254	0.31	−0.89	1.50	0.49	−0.71	1.70	0.28	−0.92	1.47
	P5-P10	0.105 ± 0.637	−0.245 ± 0.475	0.58	−0.64	1.79	0.05	−1.14	1.23	0.10	−1.10	1.28
	P5-P15	0.065 ± 0.734	0.147 ± 1.370	0.07	−1.12	1.26	0.03	−1.16	1.22	0.06	−1.13	1.24
	P10-P15	−0.040 ± 0.296	0.392 ± 1.130	0.48	−0.72	1.69	0.02	−1.17	1.21	0.16	−1.03	1.35

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 10: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
							Higher Jump			Lower Jump		
		Higher Jump	Lower Jump	g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	26.773 ± 3.937	26.195 ± 9.347	0.07	−1.11	1.26	–	–	–	–	–	–
	P1	23.203 ± 5.145	25.047 ± 9.409	0.22	−0.97	1.42	–	–	–	–	–	–
	P5	21.883 ± 2.190 †	22.228 ± 7.541	0.06	−1.13	1.25	–	–	–	–	–	–
	P10	23.353 ± 2.817	23.010 ± 8.625	0.05	−1.14	1.24	–	–	–	–	–	–
	P15	24.230 ± 3.895	25.377 ± 9.079	0.15	−1.04	1.34	–	–	–	–	–	–
	R-P1	−3.570 ± 7.143	−1.148 ± 3.403	0.40	−0.80	1.60	0.72	−0.51	1.94	0.11	−1.08	1.30
	P1-P5	−1.320 ± 4.657	−2.818 ± 3.495	0.34	−0.86	1.53	0.31	−0.89	1.50	0.31	−0.89	1.50
	P1-P10	0.150 ± 6.248	−2.037 ± 4.461	0.37	−0.83	1.57	0.03	−1.15	1.22	0.21	−0.98	1.40
	P1-P15	1.027 ± 6.882	0.330 ± 5.405	0.10	−1.08	1.29	0.21	−0.98	1.40	0.03	−1.15	1.22
	P5-P10	1.470 ± 1.854	0.782 ± 1.779	0.35	−0.85	1.55	0.54	−0.67	1.75	0.09	−1.10	1.28
	P5-P15	2.347 ± 2.849	3.148 ± 3.309	0.24	−0.95	1.43	0.69	−0.54	1.91	0.35	−0.85	1.54
	P10-P15	0.877 ± 1.243	2.367 ± 3.553	0.52	−0.69	1.72	0.24	−0.95	1.43	0.25	−0.95	1.44

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 11: Results of between and within drop jump performance subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.655 ± 0.068	0.625 ± 0.068	0.42	−0.78	1.62	–	–	–	–	–	–
	G10	0.730 ± 0.145	0.705 ± 0.091	0.19	−1.00	1.38	–	–	–	–	–	–
	G1-G10	0.074 ± 0.132	0.080 ± 0.076	0.05	−1.14	1.24	0.61	−0.61	1.82	0.92	−0.33	2.17
Maximal horizontal displacement	G1	0.120 ± 0.046	0.094 ± 0.015	0.71	−0.51	1.94	–	–	–	–	–	–
	G10	0.113 ± 0.040	0.117 ± 0.028	0.11	−1.08	1.30	–	–	–	–	–	–
	G1-G10	−0.007 ± 0.063	0.023 ± 0.041	0.53	−0.68	1.74	0.16	−1.03	1.35	0.95	−0.30	2.21
Jump height	G1	0.404 ± 0.029	0.355 ± 0.047	1.17	−0.12	2.45	–	–	–	–	–	–
	G10	0.176 ± 0.052 ‡	0.205 ± 0.061 ‡	0.47	−0.73	1.68	–	–	–	–	–	–
	G1-G10	−0.228 ± 0.066	−0.149 ± 0.080	0.98	−0.27	2.24	5.00	2.59	7.41	2.55	0.95	4.15
Mean concentric velocity	G1	1.969 ± 0.139	1.889 ± 0.243	0.37	−0.82	1.57	–	–	–	–	–	–
	G10	1.394 ± 0.225 ‡	1.549 ± 0.337	0.50	−0.70	1.71	–	–	–	–	–	–
	G1-G10	−0.575 ± 0.296	−0.340 ± 0.402	0.62	−0.60	1.83	2.84	1.16	4.53	1.07	−0.20	2.34
Peak concentric velocity	G1	3.324 ± 0.262	3.114 ± 0.273	0.73	−0.50	1.95	–	–	–	–	–	–
	G10	2.257 ± 0.406 ‡	2.413 ± 0.478 ‡	0.32	−0.87	1.52	–	–	–	–	–	–
	G1-G10	−1.067 ± 0.436	−0.701 ± 0.512	0.71	−0.51	1.94	2.88	1.19	4.58	1.66	0.28	3.04
Time to peak concentric velocity	G1	0.300 ± 0.041	0.293 ± 0.042	0.16	−1.03	1.35	–	–	–	–	–	–
	G10	0.481 ± 0.219	0.427 ± 0.194	0.24	−0.95	1.43	–	–	–	–	–	–
	G1-G10	0.181 ± 0.212	0.134 ± 0.174	0.22	−0.97	1.42	1.06	−0.21	2.33	0.88	−0.36	2.13

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher jump subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 11: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.735 ± 0.170	−1.794 ± 0.271	0.24	−0.95	1.43	–	–	–	–	–	–
	G10	−1.541 ± 0.318	−1.658 ± 0.177	0.42	−0.78	1.62	–	–	–	–	–	–
	G1-G10	0.194 ± 0.434	0.136 ± 0.303	0.14	−1.05	1.33	0.70	−0.52	1.93	0.55	−0.66	1.76
Minimal eccentric velocity	G1	−3.148 ± 0.210	−3.020 ± 0.285	0.47	−0.73	1.68	–	–	–	–	–	–
	G10	−2.409 ± 0.375 ‡	−2.588 ± 0.316 ‡	0.48	−0.73	1.68	–	–	–	–	–	–
	G1-G10	0.740 ± 0.507	0.433 ± 0.516	0.55	−0.66	1.76	2.25	0.73	3.77	1.33	0.02	2.64
RPE	P0	9.333 ± 0.516	8.833 ± 1.602	0.39	−0.81	1.59	–	–	–	–	–	–
Blood lactate concentration	R	1.683 ± 0.325	1.933 ± 0.596	0.48	−0.72	1.69	–	–	–	–	–	–
	P1	9.267 ± 2.139 †	11.650 ± 2.359 †	0.98	−0.28	2.23	–	–	–	–	–	–
	P15	12.150 ± 3.024 †	10.900 ± 4.405 †	0.31	−0.89	1.50	–	–	–	–	–	–
	R-P1	7.583 ± 2.177	9.717 ± 2.629	0.82	−0.42	2.05	4.58	2.32	6.83	5.21	2.72	7.70
	P1-P15	2.883 ± 2.095	−0.750 ± 4.997	0.88	−0.37	2.12	1.02	−0.25	2.28	0.20	−0.99	1.39
Heart rate	PRE	119.67 ± 20.49	111.33 ± 12.37	0.45	−0.75	1.66	–	–	–	–	–	–
	P0	175.00 ± 16.49 †	179.83 ± 11.41 †	0.31	−0.88	1.51	–	–	–	–	–	–
	P5	102.33 ± 15.32 ¥	94.83 ± 14.55 ¥	0.46	−0.74	1.67	–	–	–	–	–	–
	PRE-P0	55.33 ± 15.33	68.50 ± 14.14	0.82	−0.41	2.06	2.75	1.09	4.40	5.31	2.79	7.84
	P0-P5	−72.67 ± 6.65	−85.00 ± 12.00	1.17	−0.11	2.46	4.21	2.08	6.35	6.00	3.22	8.79

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher jump subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 11: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.867 ± 1.263	5.24 ± 2.350	0.31	−0.89	1.50	–	–	–	–	–	–
	P1	3.718 ± 1.571 †	3.943 ± 2.370	0.10	−1.08	1.29	–	–	–	–	–	–
	P5	4.835 ± 1.748	4.705 ± 2.953	0.05	−1.14	1.24	–	–	–	–	–	–
	P10	4.665 ± 1.352	4.573 ± 2.718	0.04	−1.15	1.23	–	–	–	–	–	–
	P15	4.730 ± 1.272	4.780 ± 2.446	0.02	−1.16	1.21	–	–	–	–	–	–
	R-P1	−2.148 ± 1.903	−1.297 ± 1.754	0.43	−0.77	1.63	1.39	0.07	2.71	0.51	−0.70	1.71
	P1-P5	1.117 ± 0.596	0.762 ± 0.795	0.47	−0.74	1.67	0.62	−0.60	1.84	0.26	−0.93	1.46
	P1-P10	0.947 ± 0.576	0.63 ± 0.816	0.41	−0.79	1.61	0.60	−0.62	1.81	0.23	−0.96	1.42
	P1-P15	1.012 ± 0.425	0.837 ± 1.283	0.17	−1.02	1.36	0.65	−0.57	1.87	0.32	−0.87	1.52
	P5-P10	−0.170 ± 0.681	−0.132 ± 0.488	0.06	−1.13	1.25	0.10	−1.09	1.29	0.04	−1.14	1.23
	P5-P15	−0.105 ± 0.742	0.075 ± 1.397	0.15	−1.04	1.34	0.06	−1.12	1.25	0.03	−1.16	1.21
	P10-P15	0.065 ± 0.313	0.207 ± 1.222	0.15	−1.04	1.34	0.05	−1.14	1.23	0.07	−1.11	1.26

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 11: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Jump	Lower Jump				Higher Jump			Lower Jump		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	26.025 ± 6.072	27.493 ± 8.785	0.18	−1.01	1.37	–	–	–	–	–	–
	P1	26.902 ± 7.477	26.622 ± 9.095	0.03	−1.16	1.22	–	–	–	–	–	–
	P5	23.240 ± 6.212	23.648 ± 7.462	0.05	−1.13	1.24	–	–	–	–	–	–
	P10	24.055 ± 6.473	24.373 ± 8.359	0.04	−1.15	1.23	–	–	–	–	–	–
	P15	24.715 ± 6.292	26.788 ± 8.527	0.26	−0.94	1.45	–	–	–	–	–	–
	R-P1	0.877 ± 1.760	−0.872 ± 3.567	0.57	−0.64	1.79	0.12	−1.07	1.31	0.09	−1.10	1.28
	P1-P5	−3.662 ± 1.834	−2.973 ± 3.431	0.23	−0.96	1.42	0.49	−0.71	1.70	0.33	−0.87	1.53
	P1-P10	−2.847 ± 2.071	−2.248 ± 4.452	0.16	−1.03	1.35	0.38	−0.82	1.57	0.24	−0.95	1.43
	P1-P15	−2.187 ± 1.986	0.167 ± 5.453	0.53	−0.68	1.74	0.29	−0.90	1.49	0.02	−1.17	1.20
	P5-P10	0.815 ± 0.801	0.725 ± 1.818	0.06	−1.13	1.25	0.12	−1.07	1.31	0.08	−1.10	1.27
	P5-P15	1.475 ± 0.772	3.140 ± 3.316	0.64	−0.58	1.86	0.22	−0.97	1.41	0.36	−0.84	1.56
	P10-P15	0.660 ± 0.684	2.415 ± 3.528	0.64	−0.58	1.85	0.10	−1.09	1.28	0.26	−0.93	1.46

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher jump subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 12: Results of between and within stretch-shortening potentiation magnitude subgroups comparisons for performance during 50 continuous CMJs

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
							Higher Potentiation			Lower Potentiation		
		Higher Potentiation	Lower Potentiation	g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Countermovement depth	G1	0.590 ± 0.031	0.663 ± 0.069 *	0.42	−0.78	1.62	–	–	–	–	–	–
	G10	0.661 ± 0.139	0.727 ± 0.093	0.19	−1.00	1.38	–	–	–	–	–	–
	G1-G10	0.071 ± 0.135	0.065 ± 0.077	0.05	−1.14	1.24	0.61	−0.61	1.82	0.92	−0.33	2.17
Maximal horizontal displacement	G1	0.101 ± 0.051	0.119 ± 0.018	0.71	−0.51	1.94	–	–	–	–	–	–
	G10	0.115 ± 0.039	0.115 ± 0.032	0.11	−1.08	1.30	–	–	–	–	–	–
	G1-G10	0.014 ± 0.074	−0.004 ± 0.028	0.53	−0.68	1.74	0.16	−1.03	1.35	0.95	−0.30	2.21
Jump height	G1	0.365 ± 0.062	0.408 ± 0.030	1.17	−0.12	2.45	–	–	–	–	–	–
	G10	0.185 ± 0.047 ‡	0.196 ± 0.066 ‡	0.47	−0.73	1.68	–	–	–	–	–	–
	G1-G10	−0.180 ± 0.095	−0.213 ± 0.065	0.98	−0.27	2.24	5.00	2.59	7.41	2.55	0.95	4.15
Mean concentric velocity	G1	1.863 ± 0.251	2.023 ± 0.161	0.37	−0.82	1.57	–	–	–	–	–	–
	G10	1.579 ± 0.182	1.409 ± 0.372 ‡	0.50	−0.70	1.71	–	–	–	–	–	–
	G1-G10	−0.284 ± 0.279	−0.614 ± 0.383	0.62	−0.60	1.83	2.84	1.16	4.53	1.07	−0.20	2.34
Peak concentric velocity	G1	3.124 ± 0.360	3.340 ± 0.182	0.73	−0.50	1.95	–	–	–	–	–	–
	G10	2.378 ± 0.286 ‡	2.307 ± 0.558 ‡	0.32	−0.87	1.52	–	–	–	–	–	–
	G1-G10	−0.746 ± 0.431	−1.033 ± 0.539	0.71	−0.51	1.94	2.88	1.19	4.58	1.66	0.28	3.04
Time to peak concentric velocity	G1	0.285 ± 0.035	0.298 ± 0.053	0.16	−1.03	1.35	–	–	–	–	–	–
	G10	0.331 ± 0.036 ‡	0.537 ± 0.253	0.24	−0.95	1.43	–	–	–	–	–	–
	G1-G10	0.047 ± 0.035	0.239 ± 0.233	0.22	−0.97	1.42	1.06	−0.21	2.33	0.88	−0.36	2.13

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; * = significantly different than higher potentiation subgroup, ‡ = significantly different than G1 within subgroup.*

Appendix 12: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Potentiation	Lower Potentiation				Higher Potentiation			Lower Potentiation		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
Mean eccentric velocity	G1	−1.709 ± 0.263	−1.813 ± 0.156	0.24	−0.95	1.43	–	–	–	–	–	–
	G10	−1.664 ± 0.233	−1.458 ± 0.228 ‡	0.42	−0.78	1.62	–	–	–	–	–	–
	G1-G10	0.044 ± 0.362	0.355 ± 0.301	0.14	−1.05	1.33	0.70	−0.52	1.93	0.55	−0.66	1.76
Minimal eccentric velocity	G1	−3.035 ± 0.310	−3.111 ± 0.228	0.47	−0.73	1.68	–	–	–	–	–	–
	G10	−2.635 ± 0.226 ‡	−2.292 ± 0.357 ‡	0.48	−0.73	1.68	–	–	–	–	–	–
	G1-G10	0.400 ± 0.461	0.819 ± 0.503	0.55	−0.66	1.76	2.25	0.73	3.77	1.33	0.02	2.64
RPE	P0	8.833 ± 1.472	8.833 ± 1.169	0.39	−0.81	1.59	–	–	–	–	–	–
Blood lactate concentration	R	1.917 ± 0.574	1.667 ± 0.266	0.48	−0.72	1.69	–	–	–	–	–	–
	P1	9.517 ± 2.265 †	11.433 ± 0.476 †	0.98	−0.28	2.23	–	–	–	–	–	–
	P15	11.917 ± 4.387 †	11.967 ± 3.489 †	0.31	−0.89	1.50	–	–	–	–	–	–
	R-P1	7.600 ± 2.597	9.767 ± 0.344	0.82	−0.42	2.05	4.58	2.32	6.83	5.21	2.72	7.70
	P1-P15	2.400 ± 3.864	0.533 ± 3.632	0.88	−0.37	2.12	1.02	−0.25	2.28	0.20	−0.99	1.39
Heart rate	PRE	112.50 ± 20.16	119.50 ± 20.89	0.45	−0.75	1.66	–	–	–	–	–	–
	P0	181.50 ± 14.78 †	171.67 ± 10.73 †	0.31	−0.88	1.51	–	–	–	–	–	–
	P5	100.67 ± 16.39 ¥	90.33 ± 14.94 †¥	0.46	−0.74	1.67	–	–	–	–	–	–
	PRE-P0	69.00 ± 19.84	52.17 ± 14.70	0.82	−0.41	2.06	2.75	1.09	4.40	5.31	2.79	7.84
	P0-P5	−80.83 ± 7.60	−81.33 ± 16.77	1.17	−0.11	2.46	4.21	2.08	6.35	6.00	3.22	8.79

*g = Hedge's g effect size; G1 and G10 = average value of initial and final five intervention jumps, respectively; LCI/UCI = lower/upper limits of 95 % confidence interval; P0, P1, P5, and P15 = measurement 0, 1, 5, 10, and 15 minutes after the final intervention jump, respectively; PRE = measurement 1 second before the initial intervention jump; R = resting value; * = significantly different than higher potentiation subgroup; ‡ = significantly different than G1 within subgroup; † = significantly different than R or PRE within subgroup; ¥ = significantly different than P0 or P1 within subgroup.*

Appendix 12: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Potentiation	Lower Potentiation				Higher Potentiation			Lower Potentiation		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Dm	R	5.188 ± 2.276	5.410 ± 1.398	0.31	−0.89	1.50	–	–	–	–	–	–
	P1	3.093 ± 1.922	3.757 ± 2.274	0.10	−1.08	1.29	–	–	–	–	–	–
	P5	3.902 ± 2.533	4.445 ± 2.391	0.05	−1.14	1.24	–	–	–	–	–	–
	P10	3.762 ± 2.114	4.287 ± 2.008	0.04	−1.15	1.23	–	–	–	–	–	–
	P15	4.267 ± 2.25	4.222 ± 1.804	0.02	−1.16	1.21	–	–	–	–	–	–
	R-P1	−2.095 ± 1.797	−1.653 ± 2.080	0.43	−0.77	1.63	1.39	0.07	2.71	0.51	−0.70	1.71
	P1-P5	0.808 ± 0.832	0.688 ± 0.305	0.47	−0.74	1.67	0.62	−0.60	1.84	0.26	−0.93	1.46
	P1-P10	0.668 ± 0.514	0.530 ± 0.368	0.41	−0.79	1.61	0.60	−0.62	1.81	0.23	−0.96	1.42
	P1-P15	1.173 ± 1.028	0.465 ± 0.633	0.17	−1.02	1.36	0.65	−0.57	1.87	0.32	−0.87	1.52
	P5-P10	−0.140 ± 0.655	−0.158 ± 0.527	0.06	−1.13	1.25	0.10	−1.09	1.29	0.04	−1.14	1.23
	P5-P15	0.365 ± 1.248	−0.223 ± 0.843	0.15	−1.04	1.34	0.06	−1.12	1.25	0.03	−1.16	1.21
	P10-P15	0.505 ± 1.009	−0.065 ± 0.440	0.15	−1.04	1.34	0.05	−1.14	1.23	0.07	−1.11	1.26

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Dm = tensiomyography muscle belly displacement; * = significantly different than higher potentiation subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*

Appendix 12: Continued

Dependent Variable	Time	Subgroup Mean ± SD		Between Subgroups Effect Size			Within Subgroups Effect Size					
		Higher Potentiation	Lower Potentiation				Higher Potentiation			Lower Potentiation		
				g	LCI	UCI	g	LCI	UCI	g	LCI	UCI
TMG-Tc	R	24.072 ± 7.003	30.338 ± 7.026	0.18	−1.01	1.37	–	–	–	–	–	–
	P1	23.675 ± 8.786	26.468 ± 8.797	0.03	−1.16	1.22	–	–	–	–	–	–
	P5	21.162 ± 7.630	24.872 ± 5.060	0.05	−1.13	1.24	–	–	–	–	–	–
	P10	22.037 ± 8.149	26.493 ± 6.020	0.04	−1.15	1.23	–	–	–	–	–	–
	P15	24.018 ± 7.873	27.582 ± 7.286	0.26	−0.94	1.45	–	–	–	–	–	–
	R-P1	−0.397 ± 2.367	−3.870 ± 7.578	0.57	−0.64	1.79	0.12	−1.07	1.31	0.09	−1.10	1.28
	P1-P5	−2.513 ± 2.631	−1.597 ± 5.257	0.23	−0.96	1.42	0.49	−0.71	1.70	0.33	−0.87	1.53
	P1-P10	−1.638 ± 3.834	0.025 ± 6.589	0.16	−1.03	1.35	0.38	−0.82	1.57	0.24	−0.95	1.43
	P1-P15	0.343 ± 3.263	1.113 ± 8.053	0.53	−0.68	1.74	0.29	−0.90	1.49	0.02	−1.17	1.20
	P5-P10	0.875 ± 1.560	1.622 ± 1.972	0.06	−1.13	1.25	0.12	−1.07	1.31	0.08	−1.10	1.27
	P5-P15	2.857 ± 1.958	2.710 ± 3.918	0.64	−0.58	1.86	0.22	−0.97	1.41	0.36	−0.84	1.56
	P10-P15	1.982 ± 3.095	1.088 ± 2.429	0.64	−0.58	1.85	0.10	−1.09	1.28	0.26	−0.93	1.46

*g = Hedge's g effect size; LCI and UCI = lower and upper limits of 95 % confidence interval, respectively; P1, P5, P10, and P15 = measurement 1, 5, 10, and 15 minute after the final intervention jump, respectively; R = resting value; TMG-Tc = tensiomyography contraction time; * = significantly different than higher potentiation subgroup; † = significantly different than R within subgroup; a, b, and c = significantly different than P1, P5, and P10 within subgroup, respectively.*