TITLE PAGE

1. *Title of the article:*
The preparation period in basketball: training load and neuromuscular adaptations

2. *Submission type:*
Original investigation

3. *Full names of the authors and institutional/corporate affiliations:*

Davide Ferioli[1], Andrea Bosio[2], Johann C. Bilsborough[3-4], Antonio La Torre[1], Michele Tornaghi[2], Ermanno Rampinini[2]

1, Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milano, Italy

2, Human Performance Laboratory, MAPEI Sport Research Centre, Olgiate Olona, Varese, Italy

3, Boston Celtics, Boston, Massachusetts, USA;

4, University Technology Sydney (UTS), Sydney, New South Wales, Australia

4. *Contact details for the corresponding author.*
Davide Ferioli
Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milano, Italy
Via Colombo 71, 20133 Milano (MI), Italy
Telephone: +39 0331881750; Fax +39 0331 881750
E-mail: davide.ferioli@unimi.it

5. *Preferred running head.*
Neuromuscular adaptations in basketball

6. *Abstract word count.*
250 words.

7. *Text-only word count.*
3500 words.

8. *Number of figures and tables.*
4 figures
5 tables.

ABSTRACT

Purpose: To investigate the 1) effect of the preparation period on the neuromuscular characteristics of 12 professional (PRO) and 16 semi-professional (SEMI-PRO) basketball players; 2) relationships between training load indices and changes in neuromuscular physical performance. **Methods:** Prior to and following the preparation period, players underwent a counter-movement jump (CMJ) test, followed by a repeated change of direction (COD) test consisting of 4 levels with increasing intensities. The peripheral neuromuscular functions of the knee extensors (peak torque, PT) were measured using electrical stimulations after each level (PT1, PT2, PT3 and PT4). Furthermore, PT Max (the highest value of PT) and PT Dec (PT decrement from PT Max to PT4) were calculated. **Results:** Trivial-to-small (effect size, ES: -0.17 to 0.46) improvements were found in CMJ variables, regardless of the competitive levels. After the preparation period, peripheral fatigue induced by a COD test was similarly reduced in both PRO (PT Dec: from 27.8±21.3% to 11.4±13.7%, ES±90%CI= -0.71±0.30) and SEMI-PRO (PT Dec: from 26.1±21.9% to 10.2±8.2%, ES±90%CI= -0.69±0.32). Moderate-to-large relationships were found between session rating of perceived exertion training load and changes in PPO measured during the CMJs (r_s ±90%CI: PPO_{abs}, -0.46±0.26; PPO_{rel}, -0.53±0.23) and in some PTs measured during the COD test (PT1, -0.45±0.26; PT2, -0.44±0.26; PT3, -0.40±0.27 and PT Max, -0.38±0.28). **Conclusions:** Preparation period induced minimal changes in the CMJ, while the ability to sustain repeated COD efforts was improved. Reaching high session rating of perceived exertion training loads might partially and negatively affect the ability to produce strength and power.

Key Words: Session RPE; Competitive level; Vertical jump; Change of direction; Peripheral fatigue.

INTRODUCTION

The quantification of training load (TL) is a common practice in basketball, with the aim to ensure that players achieve an adequate training stimulus and to reduce the negative consequences of training (i.e. risk of injury and non-functional overreaching) and the chances of undertraining.[1,2] The session rating of perceived exertion (sRPE) is a valid method to quantify the individual TL in professional (PRO) and semi-professional (SEMI-PRO) basketball players.[3,4] This low cost and user-friendly tool[2] represents a practical, reliable and valid method to monitor the athlete internal TL.[5]

The general and specific preparation periods at the beginning of the season are considered crucial phases in preparing athletes for competition. In this period, athletes begin training after a period of complete or near-to-complete rest. The initial phase (general preparation) should provide a gradual increase in TL to reduce the risk of injuries, while the remaining part of the preparation period (specific preparation) is generally characterized by higher TL compared to those observed during the competitive season. While monitoring TL in basketball is important during the preparation period,[2] data pertaining to the TLs achieved in this period are not well established in the research.[4,6-8]

The relationships between TL with changes in physical performance have been widely investigated in team sports.[9] The resulting literature on the topic, however, offers contrasting results, which indicates that the effect of TL on physical performance and fitness are not clear. In a recent study, and for the first time in basketball, a relationship between TL indicators and physical fitness variations has been established.[7] It has been suggested that high sRPE-TL during the preparation period are not essential to enhance the physical fitness levels (quantified using maximal and sub-maximal intermittent running tests) of PRO and SEMI-PRO basketball players. Due to the limited data, further insights are needed to draw definitive conclusions.

Basketball is an intermittent team sport, characterized by changes of actions every 2-3 s,[10] therefore neuromuscular abilities (i.e. power, strength, speed) are heavily taxed during basketball matches.[11] Specifically, the ability to quickly change direction and jumping performance appear to be key components of basketball.[11] Despite the importance of neuromuscular factors in basketball performance,[11] no previous study has assessed the relationships between TL indicators and changes in neuromuscular physical performance. This information may be of interest to plan an effective training process to improve performance during the preparation period. Additionally, there is limited and contrasting information regarding the effect of the preparation period on neuromuscular characteristics of basketball players. Aoki et al.[6] and Hoffman et al.[12] investigated the changes in vertical jumping performance induced by the preparation period in PRO and NCAA basketball players. PRO players demonstrated moderate-to-large improvements in squat jump height and counter-movement jump (CMJ) height, while collegiate players showed a moderate decrease in jumping performance (i.e. CMJ height). Additionally, there is limited information regarding the variations in change of direction (COD) ability across the preparation period in adult basketball players. The few studies on the topic[12,13] assessed COD ability using various COD tests in NCAA Division I or young basketball players, but the contrasting results do not allow definitive conclusions to be made. Therefore, the aims of this study were to investigate the: 1) effect of the preparation period on the neuromuscular characteristics of PRO and SEMI-PRO basketball players measured using a vertical jump test and a repeated COD test; 2) relationships between TL with changes in neuromuscular physical performance during the same period.

METHODS

Subjects

Twelve PRO and sixteen SEMI-PRO male basketball players (age: 26.2±6.5 and 23.6±4.9 years, respectively) were recruited for this study (Table 1). The PRO competed in the Italian first or second division, while SEMI-PRO were from Italian third division. During the preparation period, athletes trained 5 to 12 times a week, with 60-120 min training sessions, excluding cool down and/or stretching exercises. Standard training schedules performed by players during the preparation periods are presented in Table 2.

Table 1

Table 2

All the basketball players included in this study performed more than 80% of the team training sessions.[14] Written informed consent was received from all players after verbal and written explanation of the experimental design and potential risk and benefits of the study. An Independent Institutional Review Board approved the study in accordance with the spirit of the Helsinki Declaration.

Design

This observational study was conducted from mid-August to mid-October during the preparation period of the season 2015-16. Prior to and following this period, athletes underwent several neuromuscular evaluations, comprising of a CMJ test, followed by a repeated COD test. The individual TL of athletes was quantified during the preparation period using the sRPE method.[15]

Methodology

Neuromuscular evaluations

Athletes were assessed during the first week of training (T1) and during the weeks preceding the first or the second official competitive matches (T2) of the season. The duration of this period ranged between 5 and 7 weeks. Before each testing session, stature and body mass were measured, while body density was estimated through the skin-fold technique described by Jackson and Pollock[16] and then transformed to body fat percentage using the Siri's equation.[17] Neuromuscular evaluations were performed after a standardized warm-up consisting of a 6-min continuous run at a constant speed, followed by two sub-maximal CMJs. No stretching exercises were allowed prior to the tests. To avoid potential confounding effects of prior exercise fatigue on the outcomes variables, no heavy training sessions were performed the day preceding the neuromuscular evaluations. Both testing sessions were carried out in the same conditions (i.e. testing venue, time of the day and order/procedures of the tests).

Counter-Movement Jump Test

The CMJ test was performed using a portable force platform (Quattro Jump, Kistler, Winterthur, Switzerland) sampling at 500 Hz and its Application Software (Version 1.1.1.4). Each athlete performed 5 bilateral single CMJs from a standing position with hands placed on the hips to minimize any influence of the arms. Players were instructed to perform a quick downward movement reaching about 90° knee flexion, promptly followed by a fast-upward movement with the aim to jump as high as possible. During the concentric phase of each CMJ, absolute peak power output (PPO_{abs}), absolute peak force (PF_{abs}) and jump height were measured. Furthermore, PPO_{abs} and PF_{abs} were normalized to each athlete's body mass (PPO_{rel} and PF_{rel} respectively). The average of the best 3 values was used for analysis.

Repeated Change of Direction Test

This test aims to assess peripheral fatigue of the knee extensor (KE) muscles induced by repeated CODs. The COD test consisted of 4 levels of increasing standardized intensity. The players, paced by an audio signal, run back and forth repeatedly with 180° COD over an 8-m course. During the first and second levels, athletes carried out 11 CODs in 31.5 s and 28.5 s respectively, while the third and the fourth levels were composed of 13 CODs performed in 30.0 s and 26.0 s respectively. The instantaneous running speed sustained by each player during the COD levels was recorded using a radar device (Stalker ATS, Radar Sales, Minneapolis, MN). Furthermore, actual instantaneous metabolic power was estimated to quantify the actual exercise intensity during each COD level using the equation proposed by Di Prampero et al.[18] and then modified by Osgnach et al.[19] The peripheral neuromuscular function of the KE was assessed at baseline, prior to the standardized running warm-up, and 30 s after completion of each COD level. The neuromuscular assessments were performed in isometric conditions, measuring firstly KE torque of the right thigh and secondly KE torque of the left thigh. The athletes were seated in a purpose-built leg extension machine with the lower leg and thigh fixed at an angle of 90° from full extension. The ankle of the assessed leg was secured to the leg extension machine via Velcro® straps. The mechanical response was recorded using a load cell connected to a data acquisition system (BIOPAC MP100; BIOPAC Systems, Inc., Santa Barbara, CA) at a sampling rate of 250 Hz.

The KE contractions were induced by direct stimulation of the femoral nerve using large area electrodes (Compex, Ecublens, Switzerland) placed in the femoral triangle (cathode, 5x5 cm) and in the gluteal fold (anode, 10x5 cm). The electrodes were positioned by the same technician and their location marked on the skin. The intensity of the electrical current was defined by sending a small electrical stimulus (Digitimer DS7AH; Hertfordshire, United Kingdom; maximal voltage = 400 V), and progressively increasing the intensity by 10-mA until a plateau was reached by twitch torque values of the KE. This intensity was subsequently increased by a further 20%. The mechanical responses of the KE were then measured via the administration of 3 single stimuli, each separated by 3 s. The stimuli were produced using square pulses (200 μs). The highest value of torque production (PT) was calculated from the mean torque response of the 3 evoked contractions. The four PT values obtained at the end of each COD level were plotted against the actual corresponding metabolic power (measured by the radar system). A regression line was calculated by interpolating the four measured PT using a polynomial equation of second order. PT at 4 fixed metabolic powers (i.e. 19, 23, 27 and 31 $W \cdot kg^{-1}$) was then estimated from regression equation (PT1, PT2, PT3 and PT4 respectively, Figure 1). Furthermore, the following parameters were calculated: 1) the highest value of PT (PT Max); 2) the decrease in percentage from PT Max to PT4 (PT Dec); 3) and the metabolic power corresponding to PT Max (MP Max) (Figure 1). This procedure was carried out separately for the right and left KE muscles and the mean value of the two legs was used for analysis.

Figure 1

Training load quantification

The TL was quantified by multiplying the training/game duration in minutes (training volume, TV) by the sRPE as previously described by Foster et al.[15] sRPE were assessed using the CR-10 Borg's scale[20] and collected 30 min after each training session in each player.[21] The duration of each session was recorded individually, including within-session recovery periods and warm-up, but excluding the cool-down or stretching exercises. The match durations (warm-up included) were recorded from the beginning to the end of the game including all stops (game stops, injury stops, time-outs and in-between quarter-times stops). All players were familiar with the use of the sRPE as it had previously been utilized prior to commencing the study.

Statistical analysis

Descriptive results are reported as means ± standard deviations (SD). Assumption of normality was verified using the Kolmogorov-Smirnov test. The magnitude-based inference approach was used to analyze the data according to Hopkins et al.[22] All data were first log-transformed to reduce bias arising from non-uniformity of effects or errors.[22] Standardized differences were calculated, and interpreted as follows: ≤0.02, trivial; >0.2-0.6, small; >0.6-1.2, moderate; >1,2-2.0, large; >2.0-4.0, very large; >4.0, extremely large.[22] Probability was also calculated to compare the true (unknown) differences and the smallest worthwhile change (SWC). SWC was obtained multiplying the between-subject SD by 0.2. Quantitative chances of harmful, trivial or beneficial differences were evaluated qualitatively according to established criteria: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possible; 75-95%, likely; 95-99%, very likely; >99%, almost certain. When the probability of having higher or lower values than the SWC was less than 5%, the true difference was assessed as unclear. Due to the non-normal distribution of TV and s-RPE-TL data, spearman's rank correlation coefficients

(r_s, 90% confidence intervals) were used to determine the relationships between weekly sRPE-TL and TV with changes (%) in neuromuscular evaluations. The magnitude of relationships was assessed according to the following thresholds: ≤0.1, trivial; >0.1-0.3, small; >0.3-0.5, moderate; >0.5-0.7, large; >0.7-0.9, very large; and >0.9-1.0, almost perfect. Practical inferences of the correlations were also considered.[23] Test-retest reliability of CMJ and COD variables was determined in our laboratory on two trials in 15 and 11 amateur basketball players respectively (Table 3). Customized spreadsheets and SPSS statistical software (version 23.0, IBM SPSS Statistics, Chicago, IL, USA) were used to perform data analysis.

Table 3

RESULTS

The PRO accumulated *almost certain* greater sRPE-TL (5058±1849 vs 2373±488 AU; ES: 5.22, CL: ±1.90) and TV (909±130 vs 587±65 AU; ES: 4.68, CL: ±1.04) compared to SEMI-PRO.

Neuromuscular variations

Counter-Movement Jump Test

The CMJ variables of PRO and SEMI-PRO measured before and after the preparation period are presented in Table 4. Between-groups standardized differences for the CMJ variables are presented in Figure 2. At T1, no clear differences were found between groups, except for PPO_{abs} and PF_{abs}, which were *very likely* higher for PRO compared to SEMI-PRO (ES: 1.15, CL: ±0.63 and ES: 1.18, CL: ±0.64 respectively). At T2, PPO_{abs} and PF_{abs} resulted *likely* and *very likely* greater for PRO (ES: 0.75, CL: ±0.63 and ES: 1.20, CL: ±0.65 respectively). For the between-groups changes from T1 to T2, small differences were observed in PPO_{abs} (ES: -0.31, CL: ±0.21) and PPO_{rel} (ES: -0.52, CL: ±0.28).

Table 4

Figure 2

Repeated Changes of Direction Test

KE contractile properties (i.e. PT at fixed metabolic power) measured during the COD test are presented in Figure 3. Between-groups standardized differences for the MP Max and for the KE contractile properties measured at baseline and during the COD test are presented in Figure 4. No clear variations were observed in PT at baseline from T1 to T2 for both PRO (60.3±12.4 vs 57.2±9.6 N·m; ES: -0.23, CL: ±0.41) and SEMI-PRO (52.0±11.7 vs 51.8±10.7 N·m; ES: -0.01, CL: ±0.31). No clear variation was observed in PT Max from T1 to T2 in PRO (76.8±12.0 vs 73.8±11.5 N·m; ES: -0.24, CL: ±0.40), while a possible reduction was found in SEMI-PRO (69.1±14.6 vs 65.6±13.9 N·m; ES: -0.23, CL: ±0.28). From T1 to T2, the PT Dec was *almost certain* reduced in PRO (27.8±21.3% vs 11.4±13.7%; ES: -0.71, CL: ±0.30) and *very likely* reduced in SEMI-PRO (26.1±21.9% vs 10.2±8.2%; ES: -0.69, CL: ±0.32). After the preparation period, the MP Max was *almost certain* increased in PRO (23.5±1.4 vs 25.7±1.8 $W \cdot kg^{-1}$; ES: 1.46, CL: ±0.65) and *very likely* increased in SEMI-PRO (24.1±1.7 vs 25.2±1.8 $W \cdot kg^{-1}$; ES: 0.63, CL: ±0.47).

Figure 3

Figure 4

Relationships between training load and volume with neuromuscular variations

Within-player correlations between mean weekly sRPE-TL or TV, and variations in neuromuscular performance tested after the preparation period were obtained pooling the data of PRO and SEMI-PRO (Table 5). Moderate-to-large relationships were found between TL and changes in PPO measured during the CMJs and in some PTs (i.e. PT1, PT2, PT3 and PT Max) measured during the COD test.

Table 5

DISCUSSION

This study investigated the changes induced by the preparation period on some neuromuscular characteristics (i.e. vertical jump and COD ability) among PRO and SEMI-PRO male basketball players. The likely ineffective training stimuli or overreaching phenomenon occurred during the preparation period, given there were trivial-to-small improvements in CMJ variables, regardless of the competitive levels. Peripheral fatigue induced by a COD test was moderately reduced, suggesting that the ability to sustain repeated CODs was improved. The negative relationships found between sRPE-TL and TV with peripheral neuromuscular functions and CMJ variables, suggest that reaching high sRPE-TL and TV might negatively impact on strength and power properties.

The PRO accumulated approximately twice as much weekly sRPE-TL as SEMI-PRO during the preparation period. The mean weekly sRPE-TL sustained by PRO involved in the present study were greater than the amount previously observed by Manzi et al.[3] (5058±1849 vs 3334±256 AU). However, sRPE-TL were collected during different training phases in the two studies (i.e. preparation vs competitive period). The preparation period tends to be characterized by higher TLs compared to the competitive period of the season.[6] The mean weekly sRPE-TL sustained by SEMI-PRO athletes of the present study (2373±488 AU) was greater than the amount previously reported for Australian SEMI-PRO basketball players (~900-1200 AU).[4,8] This gap is the results of the different training interventions performed among SEMI-PRO players of these different countries, with Italian players training more times a week (5-6 vs 3 sessions/week) and for longer training session durations than the Australian players.

The average height of the CMJs[24] measured in the present study is similar to those previously reported by Ben Abdelkrim et al.[25] for elite basketball players competing in the Tunisian national team (49.7±5.8 cm) and by Shalfawi et al.[26] for professional basketball players (52.0±7.5 cm). In the present study, no statistical variation in CMJ heights and small improvement in PF were found among the two groups of players, while a small increase in PPO was observed only among SEMI-PRO. The similar or slightly improved jumping performance among the two groups could be a consequence of the ineffective exercise stimuli or, conversely, could be partially influenced by fatigue state occurred during the preparation period.[24] Power and force produced during CMJ, when considered in absolute terms (i.e. PPO_{abs} and PF_{abs}), were found to be substantially greater in PRO compared to SEMI-PRO. Therefore, the ability to produce high levels of force and power during vertical jumps might represent variables that discriminate adult players of different competitive level.[27] All together this information suggests the importance of strength and power characteristics for success in basketball.

A novel application for the quantification of peripheral fatigue induced by repeated CODs was used in the present study. The current findings suggest that the ability to sustain repeated CODs efforts may be improved after the preparation period, as peripheral neuromuscular fatigue induced by the COD test was reduced in both groups. Compared to T1, the considerably higher level of PT4 and the reduced PT Dec measured at T2 indicate that PRO and SEMI-PRO enhanced their ability to sustain repeated COD at high intensities. Indeed, the highest values of PT (i.e. PT Max) recorded during the COD test were associated with substantially higher metabolic power (i.e. MP Max) after the preparation period, despite no clear to possibly small reduction observed in PT Max and no clear variations found in PT Bas. These findings suggest that after the preparation period the post-activation potentiation phenomenon is present until a higher absolute exercise intensity and that the occurrence of fatigue is postponed. As the post-activation potentiation has shown to be primarily determined by the relative exercise intensity,[28,29] it is possible to hypothesize that the ability to produce maximal power during repeated CODs was increased. Despite the substantial differences in sRPE-TL and TV, similar neuromuscular adaptations to the COD test were found between PRO and SEMI-PRO. The *likely* greater levels of PTs (i.e. PT Bas, PT1, PT2, PT3 and PT Max) measured in PRO compared to SEMI-PRO suggest better peripheral contractile properties of the KEs for players of higher competition level. The increased ability to sustain repeated CODs efforts might be an important physical determinant for performance during matches. However, further research is required to confirm these findings.

The present study is the first to investigate the relationships between TL indicators quantified during the preparation period with changes in neuromuscular physical performance in basketball. Negative relationships were found between sRPE-TL and TV with changes in PPO measured during the CMJs (i.e. PPO_{abs} and PPO_{rel}) and PT measured during the COD test (i.e. PT1, PT2, PT3 and PT Max). Similarly, Los Arcos et al.[30] reported negative correlations between changes in neuromuscular fitness parameters (i.e. jumping and sprinting) with TV and respiratory and muscular sRPE-TL among professional soccer players. These results suggest that reaching high sRPE-TL and TV during the preparation period might negatively affect strength and power properties. This phenomenon might be ascribed to a residual fatigue that exists due to the daily training (often two daily training sessions) typical of the preparation period. However, the magnitude of these effects was small-to-large (range r_s: -0.53 to -0.26) and these relationships are not to be considered strong enough to predict the changes in neuromuscular physical performance induced by the preparation period in basketball.

Limitations of the current study are that sRPE-TL and TV were the only TL indicators quantified. No measures of external TL using microtechnology were included due to their high costs. Furthermore, due to the difficulties in assessing professional players, the duration from T1 to T2 ranged between 35 and 47 days. However, further adaptations likely did not occur in the players with extra days of training, as this period was part of the “re-activation” and “tapering” phases at the beginning of the preparation and competitive period respectively.

PRACTICAL APPLICATIONS

A high force and power production should be considered as a prerequisite for success in basketball practice, thus we suggest that strength and conditioning coaches develop training programs to proper enhance these physical characteristics. We also recommend that physical tests carried out in the present study can be used to evaluate the neuromuscular status of players across the preparation period. Basketball practitioners should consider that achieving high sRPE-TL and TV during preparation period might negatively impact strength and power properties. This is evidenced by the negative relationships between sRPE-TL and TV with changes in neuromuscular responses encountered.

CONCLUSIONS

In general, regardless of the competition level, the preparation period appears to minimally affect variables measured during vertical jump test but enhance the ability to sustain repeated COD efforts. The present results suggest that PRO basketball players can produce higher level of force and power compared to lower level basketball players.

ACKNOWLEDGEMENTS

The authors would like to thank all the athletes and the clubs involved in the study for their contribution.

REFERENCES

1. Weiss KJ, Allen SV, McGuigan MR, Whatman CS. The relationship between training load and injury in men's professional basketball players. *Int J Sports Physiol Perform*. 2017;12(9):1238-1242.
2. Fox JL, Scanlan AT, Stanton R. A review of player monitoring approaches in basketball: current trends and future directions. *J Strength Cond Res*. 2017;31(7):2021-2029.
3. Manzi V, D'Ottavio S, Impellizzeri FM, Chaouachi A, Chamari K, Castagna C. Profile of weekly training load in elite male professional basketball players. *J Strength Cond Res*. 2010;24(5):1399-1406.
4. Scanlan AT, Wen N, Tucker PS, Borges NR, Dalbo VJ. Training mode's influences on the relationships between training-load models during basketball conditioning. *Int J Sports Physiol Perform*. 2014;9(5):851-856.
5. Bourdon PC, Cardinale M, Murray A, et al. Monitoring athlete training loads: consensus statement. *Int J Sports Physiol Perform*. 2017;12(Suppl 2):S2161-S2170.
6. Aoki MS, Ronda LT, Marcelino PR, et al. Monitoring training loads in professional basketball players engaged in a periodized training program. *J Strength Cond Res*. 2017;31(2):348-358.
7. Ferioli D, Bosio A, La Torre A, Carlomagno D, Connolly DR, Rampinini E. Different training loads partially influence physiological responses to preparation period in basketball. *J Strength Cond Res*. 2017.
8. Scanlan AT, Wen N, Tucker PS, Dalbo VJ. The relationships between internal and external training load models during basketball training. *J Strength Cond Res*. 2014;28(9):2397-2405.
9. Jaspers A, Brink MS, Probst SG, Frencken WG, Helsen WF. Relationships between training load indicators and training outcomes in professional soccer. *Sports Med*. 2017;47(3):533-544.
10. Ziv G, Lidor R. Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. *Sports Med*. 2009;39(7):547-568.
11. McInnes SE, Carlson JS, Jones CJ, McKenna MJ. The physiological load imposed on basketball players during competition. *J Sports Sci*. 1995;13(5):387-397.
12. Hoffman JR, Fry AC, Howard R, Maresh CM, Kraemer WJ. Strength, speed and endurance changes during the course of a division I basketball season. *J Strength Cond Res*. 1991;5(3):144.

13. Montgomery PG, Pyne DB, Hopkins WG, Minahan CL. Seasonal progression and variability of repeat-effort line-drill performance in elite junior basketball players. *J Sports Sci*. 2008;26(5):543-550.
14. Brunelli DT, Borin JP, Rodrigues A, et al. Immune responses, upper respiratory illness symptoms, and load changes in young athletes during the preparatory period of the training periodization. *Open Access J Sports Med*. 2012;3:43-49.
15. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res*. 2001;15(1):109-115.
16. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *Br J Nutr*. 1978;40(3):497-504.
17. Siri W. Body composition from fluid space and density. In: Brozek J, Hanschel A, eds. *Techniques for Measuring Body Composition*. Washington DC: National Academy of Science; 1961.
18. di Prampero PE, Fusi S, Sepulcri L, Morin JB, Belli A, Antonutto G. Sprint running: a new energetic approach. *J Exp Biol*. 2005;208(Pt 14):2809-2816.
19. Osgnach C, Poser S, Bernardini R, Rinaldo R, di Prampero PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc*. 2010;42(1):170-178.
20. Borg G. *Borg's perceived exertion and pain scales.* Champaign, IL: Human Kinetics; 1998.
21. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*. 2004;36(6):1042-1047.
22. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3-13.
23. Hopkins WG. A Spreadsheet for deriving a confidence interval, mechanistic inference and clinical inference from a p value. In. *Retrieved from* http://sportsci.org/2007/wghinf.htm: Sportscience, 11, 16-20; 2007.
24. Claudino JG, Cronin J, Mezencio B, et al. The countermovement jump to monitor neuromuscular status: A meta-analysis. *J Sci Med Sport*. 2016;20(4):397-402.
25. Ben Abdelkrim N, Chaouachi A, Chamari K, Chtara M, Castagna C. Positional role and competitive-level differences in elite-level men's basketball players. *J Strength Cond Res*. 2010;24(5):1346-1355.
26. Shalfawi SA, Sabbah A, Kailani G, Tonnessen E, Enoksen E. The relationship between running speed and

measures of vertical jump in professional basketball players: a field-test approach. *J Strength Cond Res*. 2011;25(11):3088-3092.
27. Delextrat A, Cohen D. Physiological testing of basketball players: toward a standard evaluation of anaerobic fitness. *J Strength Cond Res*. 2008;22(4):1066-1072.
28. Baudry S, Duchateau J. Postactivation potentiation in a human muscle: effect on the rate of torque development of tetanic and voluntary isometric contractions. *J Appl Physiol (1985)*. 2007;102(4):1394-1401.
29. Place N, Casartelli N, Glatthorn JF, Maffiuletti NA. Comparison of quadriceps inactivation between nerve and muscle stimulation. *Muscle Nerve*. 2010;42(6):894-900.
30. Los Arcos A, Martinez-Santos R, Yanci J, Mendiguchia J, Mendez-Villanueva A. Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. *J Sports Sci Med*. 2015;14(2):394-401.

FIGURE CAPTIONS

Figure 1. Example of the regression line calculated by interpolating the peak torques (measured data) measured after each changes of direction level.

MP Max: metabolic power corresponding to PT Max; PT: peak torque corresponding to a metabolic power of 19 (PT1), 23 (PT2), 27 (PT3) and 31 (PT4) $W \cdot kg^{-1}$; PT Max: the highest value of PT calculated from the peak torque-metabolic power relationship; PT Dec: decrease in percentage from PT Max to PT4.

Figure 2. Standardized differences (90% confidence intervals) for the CMJ variables between professional and semi-professional players. ** likely, *** very likely difference between professional and semi-professional players. T1: test before the preparation period; T2: test after the preparation period; values above zero: greater for professional players; values below zero: greater for semi-professional players.

Figure 3. Knee extensors contractile properties measured during the COD test in professional (A) and semi-professional (B) players. ↓ decrease; ↑ increase; * possible, ** likely, *** very likely, **** almost certain change; # possible, ## likely, ### very likely difference between T1 and T2.

PT: peak torque corresponding to a metabolic power of 19 (PT1), 23 (PT2), 27 (PT3) and 31 (PT4) $W \cdot kg^{-1}$; T1: test before the preparation period; T2: test after the preparation period.

Figure 4. Between-groups standardized differences (90% confidence intervals) for the MP Max and for the knee extensor contractile properties measured at baseline and during the COD test. ** likely difference between professional and semi-professional players.

MP Max: metabolic power corresponding to PT Max; PT: peak torque corresponding to a metabolic power of 19 (PT1), 23 (PT2), 27 (PT3) and 31 (PT4) $W \cdot kg^{-1}$; PT Bas: PT measured at baseline; PT Max: the highest value of PT calculated from the peak torque-metabolic power relationship; PT Dec: decrease in percentage from PT Max to PT4; T1: test before the preparation period; T2: test after the preparation period; values above zero: greater for professional players; values below zero: greater for semi-professional players.

Table 1. Anthropometric characteristics of professional (PRO) and semi-professional (SEMI-PRO) players.

		PRO (n=12)	SEMI-PRO (n=16)
Stature (cm)		197 ± 10	188 ± 8
Body mass (kg)	T1	93.7 ± 13.0	81.8 ± 10.3
	T2	93.6 ± 12.8	81.6 ± 9.6
Body fat (%)	T1	10.9 ± 3.3	10.5 ± 4.0
	T2	10.0 ± 3.2	9.6 ± 3.6

Abbreviations: T1, before preparation period; T2 after preparation period.

Table 2. Standard training schedules performed by professional (PRO) and semi-professional (SEMI-PRO) players during the general (weeks 1-3) and the specific (weeks 4-7) preparation periods.

		PRO		SEMI-PRO	
		General preparation	Specific preparation	General preparation	Specific preparation
Monday	a.m.	Endurance	Endurance	Endurance	Rest
	p.m.	Core Stability + Technical/Tactical	Core stability + Technical/Tactical	Technical/Tactical	Speed and Agility + Technical/Tactical
Tuesday	a.m.	Strength or Endurance	Explosive strength and Power	Rest	Rest
	p.m.	Injury prevention or Endurance + Technical/Tactical	Speed and Agility + Technical/Tactical	Strength or Endurance + Technical/Tactical or Shooting session	Explosive strength and Power + Technical/Tactical
Wednesday	a.m.	Rest	Rest	Rest	Rest
	p.m.	Endurance + Shooting session or Technical/tactical	Friendly match or Technical/Tactical	Endurance or Repeated Sprint Ability	Rest or Friendly match
Thursday	a.m.	Strength or Endurance	Rest or Explosive strength and Power	Rest	Rest
	p.m.	Core stability + Technical/Tactical	Speed and Agility + Technical/Tactical	Strength + Technical/Tactical or Shooting session	Explosive strength and Power + Technical/Tactical
Friday	a.m.	Strength or Endurance	Rest or Explosive strength and Power	Rest	Rest
	p.m.	Technical/Tactical	Injury prevention + Technical/Tactical	Endurance + Technical/Tactical	Technical/Tactical
Saturday	a.m.	Rest or Pool	Shooting session or Technical/Tactical	Endurance/Core stability + Shooting session	Rest
	p.m.	Technical/Tactical	Friendly match or Technical/Tactical	Rest	Rest or Friendly match
Sunday	a.m.	Technical/Tactical or Shooting session	Rest	Day OFF	Rest
	p.m.	Day OFF	Rest or Friendly match		Rest or Friendly match

Table 3. Test-retest reliability of the outcome measures.

	%CV (90% CI)	ICC (90% CI)
	Counter-Movement Jump test	
Height	3.8 (2.8-6.1)	0.82 (0.55-0.94)
PPO_{rel}	2.9 (2.1-4.6)	0.87 (0.65-0.95)
PF_{rel}	3.8 (2.7-6.3)	0.95 (0.85-0.98)
PPO_{abs}	2.5 (1.8-4.0)	0.94 (0.83-0.98)
PF_{abs}	3.8 (2.8-6.4)	0.96 (0.87-0.99)
	Repeated Changes of Direction test	
PT bas	8.9 (6.5-14.5)	0.66 (0.24-0.87)
PT1	8.4 (6.1-13.7)	0.80 (0.51-0.93)
PT2	5.5 (4.0-8.8)	0.87 (0.66-0.96)
PT3	5.1 (3.8-8.3)	0.89 (0.72-0.96)
PT4	8.1 (5.9-13.2)	0.91 (0.75-0.97)
PT Max	5.3 (3.9-8.6)	0.88 (0.68-0.96)
PT Dec	5.3 (3.9-8.5)	0.78 (0.47-0.92)
MP Max	4.6 (3.4-7.4)	0.87 (0.65-0.95)

Abbreviations: abs, absolute; CI: Confidence intervals; %CV: coefficient of variation in percentage; ICC: intraclass correlation coefficient; MP Max: metabolic power corresponding to PT Max; PF, peak force; PPO, peak power output; PT: peak torque corresponding to a metabolic power of 19 (PT1), 23 (PT2), 27 (PT3) and 31 (PT4) $W{\cdot}kg^{-1}$; PT Bas: PT measured at baseline; PT Max: the highest value of PT calculated from the peak torque-metabolic power relationship; PT Dec: decrease in percentage from PT Max to PT4; rel, relative – normalized to body mass.

Table 4. CMJ variables of professional (PRO) and semi-professional (SEMI-PRO) players before (T1) and after (T2) the preparation period.

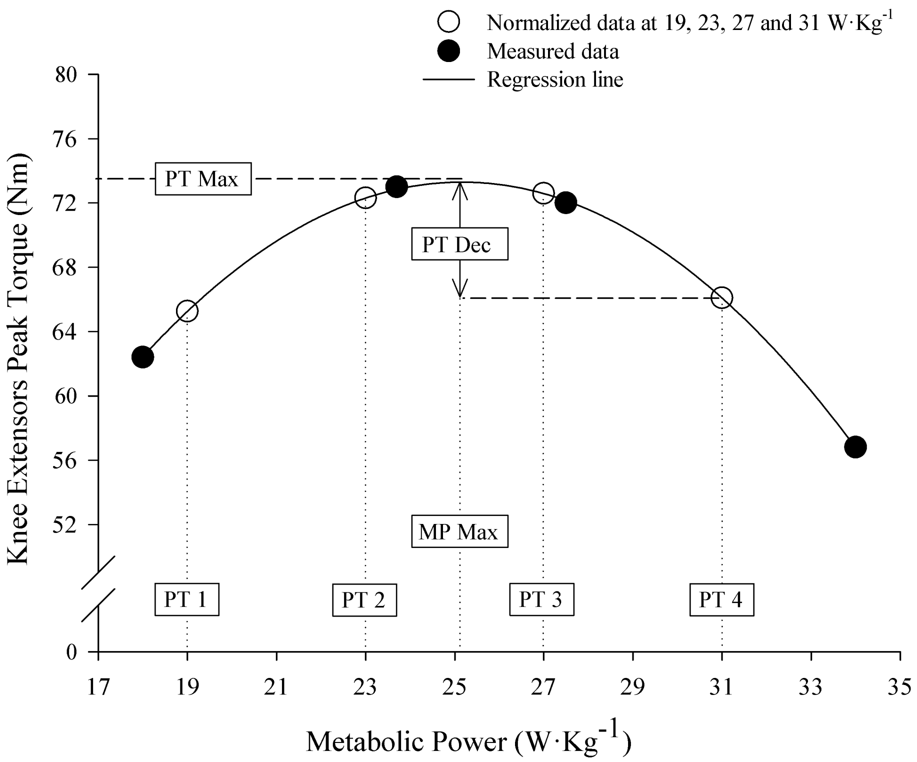
	Team	n	T1	T2	ES (90% CL)	MBI (%)	Likelihood and magnitude
Height (cm)	PRO	12	50.3 ± 5.4	49.3 ± 5.8	-0.17 ± 0.26	2/51/47	Possibly harmful
	SEMI-PRO	16	49.4 ± 5.4	49.8 ± 6.2	0.07 ± 0.21	13/85/3	Likely trivial
PPO_{rel} ($W \cdot kg^{-1}$)	PRO	12	55.4 ± 5.7	54.9 ± 5.6	-0.10 ± 0.19	1/78/21	Likely trivial
	SEMI-PRO	16	53.9 ± 5.1	56.3 ± 6.1	0.45 ± 0.22	96/4/0	Very likely beneficial
PF_{rel} ($N \cdot kg^{-1}$)	PRO	12	25.7 ± 1.9	26.7 ± 2.2	0.46 ± 0.45	84/15/1	Likely beneficial
	SEMI-PRO	16	25.6 ± 2.0	26.3 ± 2.2	0.32 ± 0.37	72/27/1	Possibly beneficial
PPO_{abs} (W)	PRO	12	5153 ± 593	5107 ± 650	-0.07 ± 0.17	1/87/13	Likely trivial
	SEMI-PRO	16	4405 ± 667	4589 ± 696	0.26 ± 0.16	79/21/0	Likely beneficial
PF_{abs} (N)	PRO	12	2397 ± 262	2492 ± 338	0.34 ± 0.34	72/27/1	Possibly beneficial
	SEMI-PRO	16	2087 ± 249	2135 ± 218	0.18 ± 0.27	56/43/1	Possibly beneficial

Abbreviations: abs, absolute; CL, confidence limits; ES, effect size; MBI, magnitude-based inferences; MBI (%), percent chances of beneficial/trivial/harmful effects; PF, peak force; PPO, peak power output; rel, relative – normalized to body mass; T1, before preparation period; T2 after preparation period.

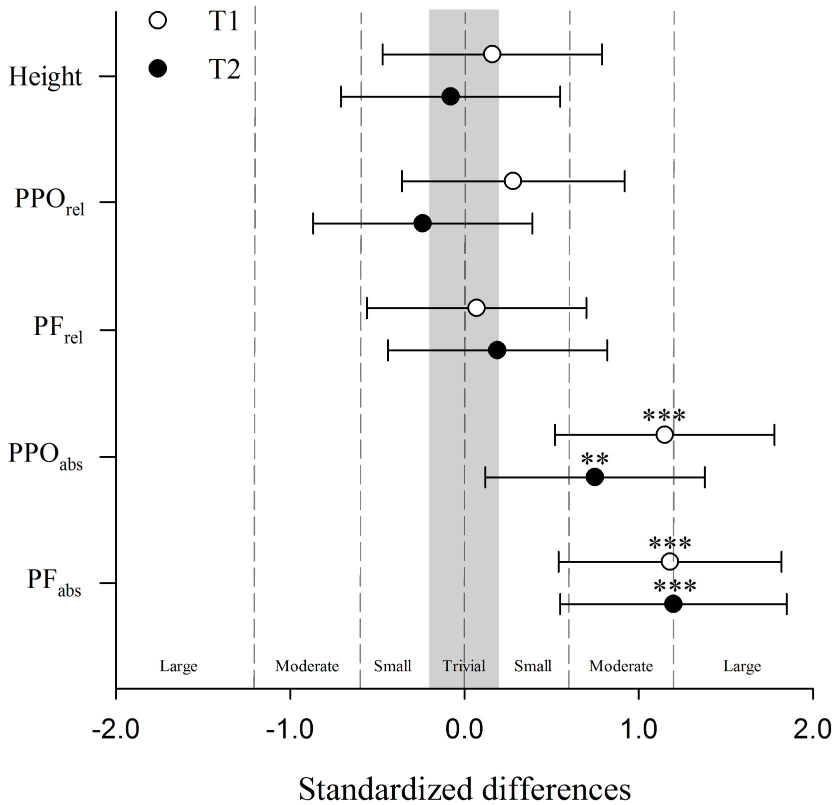
Table 5. Within-player correlations between mean weekly sRPE-TL and training volume, and changes in neuromuscular evaluations from T1 to T2.

		Weekly sRPE-TL			Weekly volume		
	n	r_s (90% CL)		Rating	r_s (90% CL)		Rating
				Counter-Movement Jump test			
Height	28	-0.32	±0.29	Likely moderate	-0.31	±0.29	Likely moderate
PPO_{rel}	28	-0.53	±0.23	Very likely large	-0.52	±0.24	Very likely large
PF_{rel}	28	-0.10	±0.31	Unclear	-0.09	±0.32	Unclear
PPO_{abs}	28	-0.46	±0.26	Very likely moderate	-0.50	±0.25	Very likely moderate
PF_{abs}	28	-0.06	±0.32	Unclear	-0.07	±0.32	Unclear
				Repeated Changes of Direction Test			
PT Bas	28	-0.17	±0.31	Unclear	0.18	±0.31	Unclear
PT1	28	-0.45	±0.26	Very likely moderate	-0.26	±0.30	Likely small
PT2	28	-0.44	±0.26	Very likely moderate	-0.31	±0.29	Likely moderate
PT3	28	-0.40	±0.27	Likely moderate	-0.38	±0.28	Likely moderate
PT4	28	-0.05	±0.32	Unclear	-0.16	±0.31	Unclear
PT Max	28	-0.38	±0.28	Likely moderate	-0.26	±0.30	Likely small
PT Dec	28	0.07	±0.32	Unclear	-0.07	±0.32	Unclear
MP Max	28	0.08	±0.32	Unclear	0.05	±0.32	Unclear

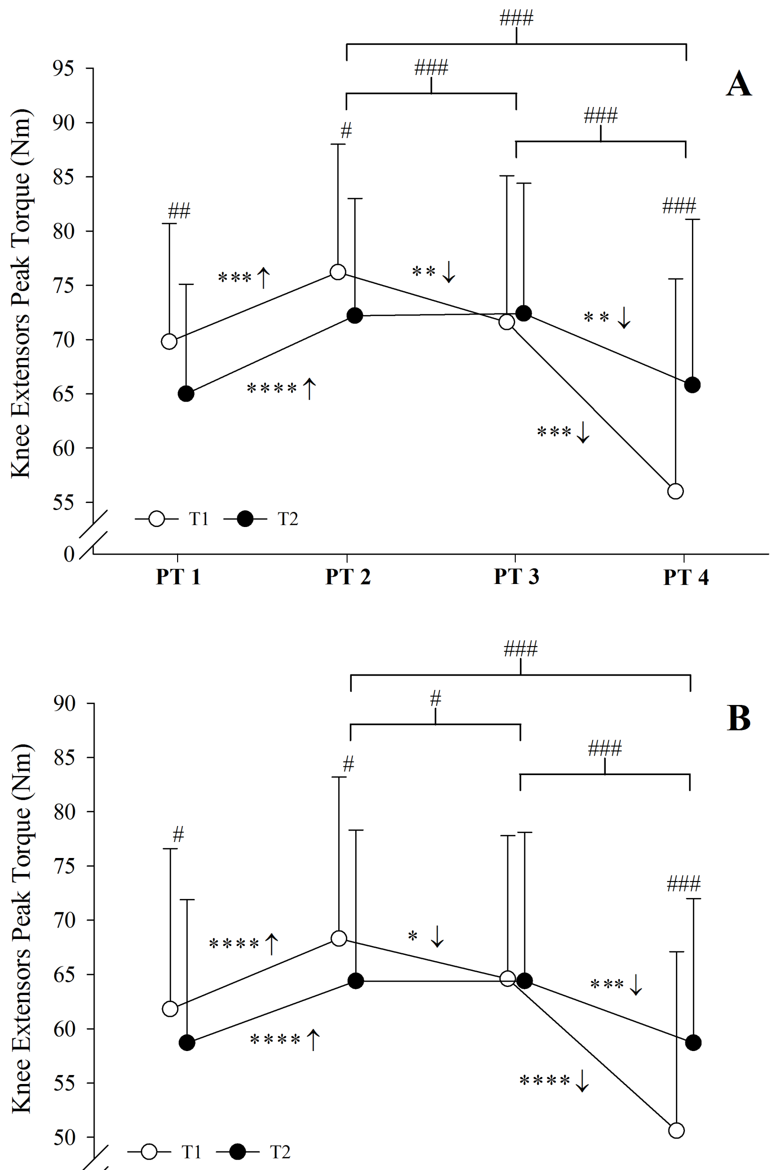
Abbreviations: r_s = Spearman's rank correlation coefficient; abs, absolute; CL: Confidence limits; MP Max: metabolic power corresponding to PT Max; PF, peak force; PPO, peak power output; PT: peak torque corresponding to a metabolic power of 19 (PT1), 23 (PT2), 27 (PT3) and 31 (PT4) $W \cdot kg^{-1}$; PT Bas: PT measured at baseline; PT Max: the highest value of PT calculated from the peak torque-metabolic power relationship; PT Dec: decrease in percentage from PT Max to PT4;rel, relative – normalized to body mass; sRPE-TL: session-rating of perceived exertion training load; T1: test before the preparation period; T2: test after the preparation period.



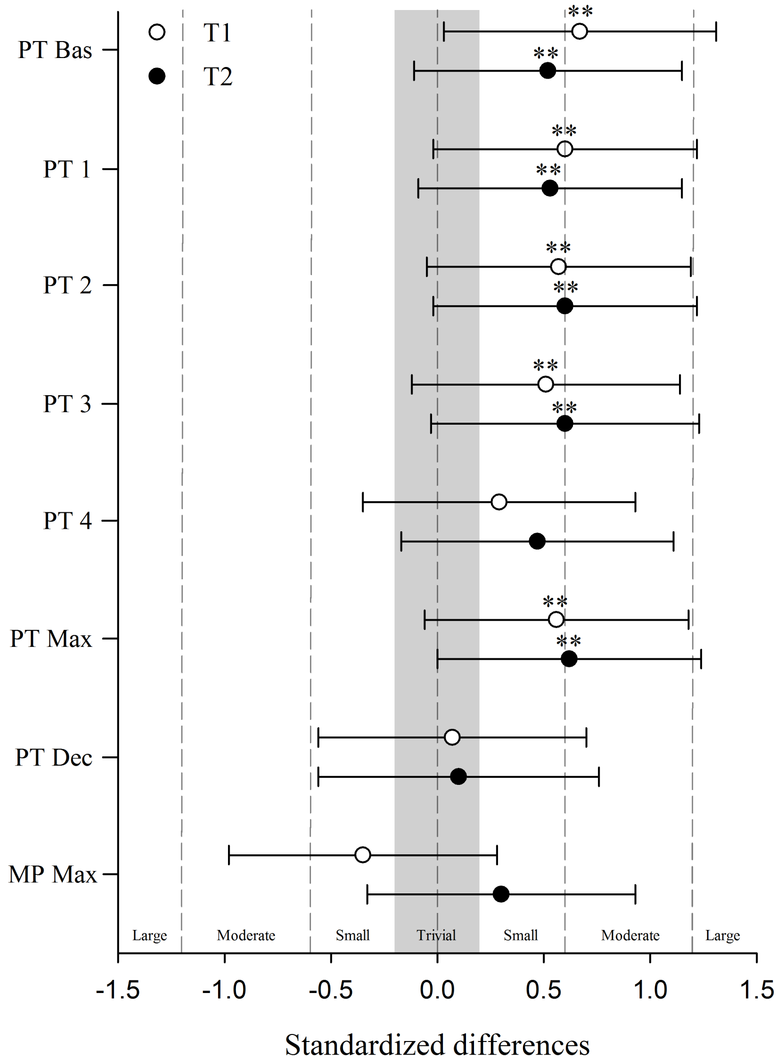
Normalized data at 19, 23, 27 and 31 W·Kg-1
Measured data
Regression line
Knee Extensors Peak Torque (Nm)
80
76
72
68
64
60
56
52
0
PT Max
PT Dec
MP Max
PT 1
PT 2
PT 3
PT 4
17
19
21
23
25
27
29
31
33
35
Metabolic Power (W·Kg-1)



T1
T2
Height
PPO_{rel}
PF_{rel}
PPO_{abs}
PF_{abs}
***
**
***
***
Large
Moderate
Small
Trivial
Small
Moderate
Large
-2.0
-1.0
0.0
1.0
2.0
Standardized differences



A
Knee Extensors Peak Torque (Nm)
95
90
85
80
75
70
65
60
55
0
PT 1
PT 2
PT 3
PT 4
T1
T2
###
###
###
##
#
###
***↑
****↑
**↓
**↓
***↓
B
Knee Extensors Peak Torque (Nm)
90
85
80
75
70
65
60
55
50
0
PT 1
PT 2
PT 3
PT 4
T1
T2
###
#
###
#
#
###
****↑
****↑
*↓
***↓
****↓



T1
T2
PT Bas
PT 1
PT 2
PT 3
PT 4
PT Max
PT Dec
MP Max
Large
Moderate
Small
Trivial
Small
Moderate
Large
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Standardized differences