SEASONAL VARIATION IN ISOKINETIC PEAK TORQUE IN YOUTH SOCCER PLAYERS

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Abstract

The aim of the study was to investigate the seasonal variation in the strength of the knee flexors and extensors in highly trained youth soccer players. The players (n=16; age 16.7±0.7) were measured at the end of the competitive season, at the beginning of the off-season and during the sixth week of a new competitive season. Isokinetic concentric peak torque was measured at $60°\cdot s^{-1}$, $180°\cdot s^{-1}$, $360°\cdot s^{-1}$ in a sitting position. The testing range of motion was set from 10–90° of knee flexion. Players performed a set of six maximal repetitions for both dominant and non-dominant limb. Average values of peak torque significantly changed during the observed periods. Significant differences ($p<.05$) between the three measurement sessions were noted with respect to the knee flexors at all angular velocities. A *post-hoc* test confirmed a significant increase between the first and **the** second measurement for flexion in both dominant ($180°\cdot s^{-1}$; $p=.033$) and non-dominant legs ($360°\cdot s^{-1}$; $p=.004$). A significant increase was also found between the first and **the** third session for both limbs during knee flexion **at all angular velocities**. The results indicate that **peak torque** values of knee flexors and extensors varied differently in trained youth soccer players depending on muscle group and movement velocity with statistically significant changes in knee flexors only.

Key words: knee extensors, knee flexors, periodization, strength, training

Introduction

Important components of soccer-specific **physical** fitness are running acceleration, anaerobic repeated sprint ability and explosive power of lower extremities. These components are used in particular during running, kicking, jumping, and tackling (Bradley**, et** al, 2009; Bravo**, et** al., 2008; Verheijen, 1998). All of these movements are associated with the production of dynamic force during knee extension and flexion. The knee extensors are the prime movers involved in running, jumping and kicking the ball**,** and the knee flexors in running and stabilizing the knee joint when changing direction (Cerrah**, et** al., 2011; Newman, Tarpenning, & Marino, 2004;

Stølen, Chamari, Castagna, & Wisloff, 2005). Strength of knee flexors and extensors and their ratio have also been identified as important criteria **to** injury risk of the lower extremities (**Hughes** & Watkins, 2006; Proske, Morgan, Brockett, & Percival, 2004).

To improve muscle strength and power during an annual training cycle, successive training phases focus on different neuromuscular adaptations within the time frame of the periodization (Fleck & Kraemer, 2004; Wirth & Schmidtbleicher, 2007). During the off-season general muscle strength should be developed based on the results of **end-of-season** musculoskeletal and movement screening. In the pre-season strength training would include maximum strength development which is followed by its conversion to soccer-specific strength and explosive power for performing intensive soccer movements (Schmid & Alejo, 2002; Stølen**, et** al., 2005; Ratamess, 2008). During the competitive season it is important to maintain the improved muscle strength and power and, especially in young players, to further increase it. After a period of active **rest,** which comes after the competitive season during which time nonspecific lower intensity exercises **prevail,** the loss of adaptations may happen (Issurin, 2010; Mujika & Padilla, 2000b).

Isokinetic dynamometry is considered an objective and reliable diagnostic tool which enables **practitioners** to identify torque through a given range of movement and during varying limb velocities (Baltzopoulos & Brodie, 1989; Dirnberger, Kösters, & Müller, 2012). Wrigley (2000) suggested that isokinetic testing of knee flexors and extensors is reliable and sensitive enough to explore seasonal changes in soccer players' strength which probably **occur** due to training load during the varying training phases.

Although a great number of studies have focused on the evaluation of isokinetic strength of lower extremities in soccer players, most of these studies have been focused only on changes of isokinetic strength of knee flexors and extensors after a training program applied **during the** pre-season (Askling, Karlsson, & Thorstensson, 2003; Gioftsidou, Beneka, Malliou, Pafis, &

Godolias, 2006; Gioftsidou**, et** al., 2008) or during the competitive season (Brito et al., 2010; Steffen, Bakka, Myklebust, & Bahr, 2008). However, it remains to be identified how muscle strength of the knee flexors and extensors **is** altered throughout the annual training cycle in elite youth male footballers and how this variation may influence both performance level and risk of injury.

Only in one study (Malliou, Ispirlidis, Beneka, Taxildaris, & Godolias, 2003) has isokinetic strength of the knee extensors been measured in adult professional soccer players at the end of season, after post-season and after pre-season. The results indicated no significant change in isokinetic peak torque (PT) values during the three observed time periods. One other study (Eniseler, Sahan, Vurgun, & Mavi, 2012) has determined PT of the knee flexors and extensors at three different velocities in adult professional soccer players over the course of 24 weeks (pre-season and competitive season). The results showed that PT changed significantly at the highest movement velocity only ($500°\cdot s^{-1}$).

The available data, taken from a limited number of studies **with** elite adult soccer players, indicates that there is a minimal change in strength parameters between different phases of a soccer training cycle. However, these **findings** may not be applicable to teenage boys because of developmental changes in strength during normal growth and maturation (De Ste Croix, Deighan, & Armstrong, 2003). To our knowledge **not any study has** investigated changes in PT during **various** training **phases** in youth soccer players, including the off-season. **Moreover,** there is limited information explaining changes in PT at different angular velocities in youth soccer players. Therefore the aim of the study was to investigate the seasonal variation in isokinetic strength of the knee flexors and extensors in highly trained youth soccer players over a range of movement velocities.

Methods

Subjects

The study involved a group of soccer players (n=16; age 16.7±0.7 years; body height 177.6±6.0 cm; body weight 66.5±9.1 kg) who played in the Czech U17 first league (Table 1). All **the** players self-reported the right leg as their dominant leg. Leg dominance was verified (preferred kicking leg) before testing. The study was approved by the institution ethics committee and conformed to the Declaration of Helsinki regarding the **participation** of human subjects. All tested players were fully informed about the aim of the study and the testing procedures that would be employed in the study. Written informed consent agreeing to the testing procedures and the use of the data for further research was obtained. Players with acute medical problems and with a history of **knee-related** injury were excluded from the research. The day before **testing the** players were not exposed to any high training load, and **they** especially avoided eccentric training.

Isokinetic dynamometry

Prior to testing the players completed a non-specific **warm-up**, which included cycling on a stationary bicycle ergometer Giro M (Heinz Kettler GmbH & Co. KG, Ense, Germany) for **six** minutes at a self-regulated low to moderate intensity and **five** minutes of stretching exercises which targeted the main muscle groups involved during testing. The warm-up routine was performed under the supervision of the researcher.

Bilateral strength of the concentric action of the knee flexors and extensors was measured using **the** isokinetic dynamometer IsoMed 2000 (D. & R. Ferstl GmbH, Hemau, Germany). The players were tested in a sitting position with a hip angle of 100°. For fixation of the pelvis and thigh of the tested leg, fixed straps were used; shoulders were fixed by shoulder pads in the ventral-dorsal and cranial-caudal direction. The axis of rotation of the dynamometer was aligned with the axis of rotation of the knee (lateral femoral epicondyle). The arm of the dynamometer lever was fixed to the distal part of the shin and the lower edge of the shin pad was placed 2.5 cm over the medial apex malleolus. Individual seat settings were stored in PC memory before measuring the right leg and were automatically activated in the process of measuring the left **leg, and follow up-testing,** respectively. At the beginning of **the follow-up** testing individual settings were rechecked and adjusted if necessary. **The participants** were instructed to hold the handgrips located at the side the seat during all testing efforts.

Angular velocities of $60°\cdot s^{-1}$, $180°\cdot s^{-1}$ and $360°\cdot s^{-1}$ were used for the measurement in the **ascending order,** from the lowest to the highest velocity. Static gravitational correction was applied according to the manufacturer's procedures. The testing range of motion was 80° and was set from 10–90° of knee flexion (with 0° **being the** full voluntary extension). The testing protocol consisted of two sets for each velocity. In the first **warm-up** set the players performed five concentric/concentric reciprocal actions (with flexion movements performed first) with a progressive rise in the muscle action until a maximal action was performed. After a 30-second rest**, the** players performed a set of six maximal repetitions. The rest time during the measurements at different velocities was **one** minute and the rest time between the measurement of the right and left leg was **three** minutes.

During the testing procedure the players were provided with concurrent visual feedback in the form of an isokinetic strength curve displayed on the dynamometer monitor. As players' weight did not significantly change during the observed period (Table 1), absolute PT (Nm) was used for the purposes of assessment of seasonal variations (relative values of PT were only expressed in case of comparison with the results of other studies).

Measurement sessions

Three measurement sessions were undertaken during **three** phases of the training process – the first measurement was three days after the competitive season **cessation**, the second measurement on the first day of the off-season after a three-week period without **training,** and the third measurement in the sixth week of the new competitive season (Figure 1). In case of the first and the third measurement **training** load was reduced two days before the testing session. In case of the second measurement the players were recommended to avoid demanding physical activity two days before the testing session.

Training ***programme***

Training **contents,** including matches and recovery periods were recorded and values of approximate duration of the contained types of activities used with **regard** to main training effects were calculated based on the training **programme** (including training adaptations made by the coach) (Table 2).

Statistical analysis

The mean and standard deviation values were calculated for PT. One-way ANOVA for repeated measurements was used to determine the significance of differences in PT between **the** measurement sessions ($p<$**.05**). The statistical significance of the differences between the results of particular measurements was verified by a *post-hoc* Scheffe's test. The effect size was assessed by the "Eta squared" coefficient (.01–.05 low effect; .06–.13 middle effect; >.14 large **effect) (Cohen**, 1988). Statistical analysis was performed using the data analysis software system ***Statistica***, version 10 (StatSoft, Inc., Tulsa, USA).

Results

PT values for flexion and extension of the dominant and non-dominant lower leg (DL and NL, respectively) for all **the** three **measurement** occasions can be seen in Table 3. A significant effect of time was observed for both the DL and NL knee flexion at all **the** three angular velocities ($p<.05$), while measurement time was not a statistically significant factor for PT in knee extension of both lower extremities at all **the** applied angular velocities (Table 4).

Post-hoc analysis (**Figures** 2–7) revealed a statistically significant increase in PT from the 1st to the 2nd measurement but only for DL flexion PT at 180°·s^{-1} and NL flexion PT at 360°·s^{-1} (**Figures** 4, 7). However, in the 3rd measurement knee flexion PT was significantly higher compared to the 1st measurement at all angular velocities (**Figures** 2–7). In the monitored training phases **the** average flexor and extensor PT values changed in a non-uniform manner depending **on** the muscle group examined and the movement velocity. PT during knee flexion at all **the** angular velocities gradually increased from the 1st to the 3rd measurement for both lower extremities (**Figures** 2–7). During knee extension of DL and NL at **the** angular velocity of 60**°·s^{-1},** a PT decrease was observed in the 2nd measurement followed by an increase in the 3rd measurement. A similar trend was observed for NL extension at 180°·s^{-1}. On the contrary, PT of DL extensors at 180°·s^{-1} slightly i**ncreased** from the 1st to the 3rd measurement. At 360°·s^{-1} a decrease for DL extensors was observed from the 1st to the 2nd measurement followed by an increase in the 3rd measurement, whereas the trend for NL extensors was the opposite (an increase in PT from the 1st to the 2nd measurement and then a decrease in the 3rd measurement).

Discussion and conclusions

The results of the current study indicate that knee flexors PT changes significantly throughout **the** monitored **phases** in contrast to no change in knee extensors PT in elite male youth soccer players. Changes in knee flexor and extensor PT in the current group of players could be influenced by the initial level of strength achieved by training. Therefore, the findings of the current study, irrespective of the training phase, were compared with the results of previous studies with similar age groups (Forbes, Sutcliffe, Lovell, McNaughton, & Siegler, 2009; Iga, George, Lees, & Reilly, 2009; Kellis, Geodimos, Kellis, & Manou, 2001; Lehance, Binet, Bury, & Croisier, 2009; Lehnert, Urban, Prochazka, & Psotta, 2011; Maly, Zahalka, & Mala, 2013). The comparison of PT values demonstrate that the PT values achieved by the players in the current study are comparable to the values found for youth elite players in other studies (extension PT at 60°·s^{-1}: DL 151±31–211.1±38 Nm; NL 153.1±25–199±38 Nm; flexion PT at 60°·s^{-1}: DL 84.1±17–129.9±23 Nm; NL 95.3±72–124.4±22 Nm).

The main purpose of this study was to explore the **in-season** variation in PT of knee flexors and extensors in elite youth footballers. The isokinetic strength of the knee flexors for all **three measurements** at all **the** selected velocities was gradually increased for both lower extremities, where the increment increased with the velocity of movement. Throughout the **monitored phases** flexion PT increased at velocities of $60°·s^{-1}$, $180°·s^{-1}$ and $360°·s^{-1}$ by 10, 14 and 26% (DL) and by 8, 21 and 39% **(NL),** respectively.

The current data demonstrated an increase in flexion PT after post-season (after a three-week period without organized training). Differences were statistically significant for flexion PT at $180°·s^{-1}$ for DL and **at** $360°·s^{-1}$ for NL. The improvement in flexion PT is surprising because in this period the players were not subjected to the organized strength training or organized match play. One of the possible explanations may be a short-term decrease in training load during the rest phase and the disappearance of any residual fatigue, which **probably** reduced strength production **in the earlier phase**. Previous studies have indicated that the acute effects of fatigue are significantly greater in the hamstrings compared with the quadriceps in professional adult male soccer players (Sangnier & Tourny-Chollet, 2007). These detrimental **of fatigue** effects have significant implications for injury risk through increased tibial anterior shear forces and for player performance. However, whether chronic fatigue from **season-long** match play is significantly greater in the hamstrings compared with the quadriceps remains to be investigated, especially in youth populations.

Increased PT of knee flexion observed in the third measurement in both lower extremities may possibly be attributed to the specific training load **in pre-season** and at the beginning of the **new** competitive season, during which fast muscle actions appeared frequently in **soccer-specific** exercises, game activities and fitness exercises (Morrissey, Harman, & Johnson, 1995; Folland & Williams, 2007). When interpreting the test results at $360°·s^{-1}$ attention must also be drawn to the greater variability of isokinetic testing at high velocities which may account for greater differences at higher velocities of movement (Lehance**, et** al., 2009; Malliou**, et** al., 2003).

In comparison with the observed trend of increased PT in flexion, no significant changes in knee extension PT for both lower extremities were observed in the players during **different** phases of the annual training cycle. However, values for extension PT changed differently depending on movement velocity and time point.

There was a reduction in PT at $60°\cdot s^{-1}$ **in** the 2nd measurement that might be attributed to an absence of structured strength training during the post-season (Rattamess, 2008; Mujika & Padilla, 2000a). The players were **not involved** in individual training plans for this phase and this should have been a phase of active rest, with minimal strength training undertaken (Mujika & Padilla, 2000b).

As expected, extension PT increased at all velocities **in** the third measurement in comparison with the PT values in the second measurement. However, an interesting finding of this study is the decrease (DL) and/or the plateauing (NL) of strength of knee extensors observed at $60°\cdot s^{-1}$ from **the** post-season to the beginning of competitive season (Figure 2 and 3). At **movement** velocity of $180°\cdot s^{-1}$ and $360°\cdot s^{-1}$ PT values increased, although not significantly, and did not differ from **the** values found **in** the first measurement. One potential reason for the PT decrease at $60°\cdot s^{-1}$ could be **the** absence of resistance strength training. In pre-season core training and moderate intensity plyometric exercises **were used** with the main goal to induce specific neural adaptations in order to optimize the performance in a soccer player's explosive activities (post-activation potentiat**ion) (Be**hm & Sale, 1993; Wathen, Baechle, & Earle, 2008). In the competitive season the **training programme** included specific strength band exercises of lower extremities used only once every 14 days for 30 minutes.

However, a previous study of youth soccer players also observed no significant changes in isokinetic leg strength, vertical jump and sprint performance after the pre-season training

programme despite players **had been** performing high-resistance strength training and/or power training two to three times a week (Lehnert, Psotta, & Botek, 2012). Possible explanation of the absence of positive changes could be the **fact that** traditional periodization of training was applied during the off-season and competitive season. This approach is typical of simultaneous development of many targeted abilities although each of them requires specific physiological, morphological and psychological adaptations, and many applied workouts are not compatible. **Therefore,** the training effect is reduced and the ability to maintain peak performance is limited and does not reflect the requirements of the competitive calendar (Issurin, 2010).

Our results are comparable with the results of **the** study **by** Malliou**,** et al. (2003), despite the fact that they tested adult professional soccer players. The timing of the measurements was similar to our study (1st after season, 2nd after post-season, 3rd after pre-season) and the authors also reported stagnation and even a small decrease in extensor PT at velocities **of** $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ over the total time period. Our findings do not support the view that traditional soccer training produces a quadriceps dominant youth player (Iga**, et** al., 2009). Iga**, et** al (2009) compared isokinetic PT of knee joint muscle in three groups of youth soccer players and contrary to our study the authors suggest that the muscle loading **patterns,** experienced during traditional youth male soccer **training, produced** a **quadriceps-dominant** athlete.

When interpreting the results of PT of knee extensors in the observed group, two more aspects have to be taken into account. Firstly, a comparison to the results of adult elite players (Lehance**, et** al., 2009; Malliou**, et** al., 2003; Maly, Zahalka, & Mala, 2011) **indicates** that the players in the current study have not reached the strength level typical of senior players. This could imply that there is a need to further increase the training load before adaptations will be seen. Secondly, when interpreting changes in knee extension PT during the annual training **cycle,** it is important to consider measurement error of isokinetic testing. Although the reproducibility for the IsoMed 2000 dynamometer in measuring concentric and eccentric knee extension has been reported as being high (Dirnberger**,** et al, 2012), the **day-to-day** variation of isokinetic measurements is around 8.1% (Westing, Seeger, Karlson, & Ekblom, 1988).

In conclusion, the results of the current study indicate that isokinetic strength of knee flexors and extensors changed in elite youth soccer players who were actively involved in an annual training cycle at a professional soccer club. However, the changes in PT values of the knee flexors and extensors are highly variable depending on muscle group and movement velocity. Our findings do not support the view that traditional soccer training in youth soccer players produces a **quadriceps-dominant** athlete. However, the suggestion that the hamstrings appear to have residual fatigue at the end of the competitive season has important implications for in-season training and recovery processes to avoid the increase in injury risk and to **optimize** performance.

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Table 1. Body weight of the subjects for individual measurements (n=16)

Variable	M	SD	Mdn	Min	Max
Weight_1	66.5	9.1	65.5	46.6	85.2
Weight_2	64.7	8.3	63.4	46.3	82.2
Weight_3	65.1	8.3	64.5	47.3	82.2

Legend: 1, 2, 3 – order of measurement; M – mean; Mdn – median;

Min – minimum value; Max – maximum v**alue**; SD – standard deviation.

Table 2. Indicators of training load during off-season and pre-season (5 weeks) and competitive season (5 weeks)

Type of training	Off-season +Pre-season (min)	Competitive season (min)
Physical fitness training		
Strength and power training	362*	142**
Speed and agility training	370	232
Aerobic training	652	277
Skill-oriented training		
Technical-tactical training	926	645
Game-like training	945	368
Matches	1355	630
Regeneration	445	270
TOTAL	5055	2540

Legend: *core training and plyometric training (once a week); **core training or resistance band training (alternatively once a week).

Table 3. Peak torque (Nm) during concentric knee flexion and extension in the observed phases of annual training cycle (n=16)

Parameter	1st **measurement**		2nd **measurement**		3rd **measurement**	
	M	SD	M	SD	M	SD
DL-PT-F-60	118.4	19.5	122.1	20.9	129.9	23.9
DL-PT-E-60	211.1	38.6	203.9	35.4	207.1	35.2
NL-PT-F-60	114.9	15.5	118.3	22.2	124.4	22.7
NL-PT-E-60	194.8	38.8	185.3	36.5	194.7	31.8
DL-PT-F-180	98.1	21.07	108.3	14.8	111.6	17.5
DL-PT-E-180	151.5	23.9	152.9	20.8	157.4	18.8
NL-PT-F-180	95.0	20.4	102.9	22.5	114.6	18.9
NL-PT-E-180	144.4	21.3	143.3	18.5	150.6	19.0
DL-PT-F-360	73.6	24.3	83.5	26.4	92.3	22.8
DL-PT-E-360	112.3	27.3	110.9	30.5	120.9	24.2
NL-PT-F-360	70.7	26.3	93.7	20.1	96.6	23.5
NL-PT-E-360	105.0	32.3	116.5	17.8	112.3	28.1

Legend: DL – dominant leg; NL – **non-dominant** leg; PT – peak torque; F – flexors; E – extensors; 60, 180, 360 – angular velocities ($°·s^{-1}$); M – mean; SD – standard deviation.

Table 4. Differences in peak torque (Nm) during concentric knee flexion and extension in the observed time period of annual training cycle (n=16)

Parameter	Flexion			Extension		
	F	p	η^2	F	p	η^2
DL $60°·s^{-1}$	4.363	.022	.225	0.877	.423	.056
NL $60°·s^{-1}$	3.912	.031	.207	0.693	.508	.044
DL $180°·s^{-1}$	7.378	.002	.330	1.289	.290	.079
NL $180°·s^{-1}$	9.204	<.001	.380	1.129	.337	.070
DL $360°·s^{-1}$	4.505	.019	.231	2.268	.121	.131
NL $360°·s^{-1}$	10.130	<.001	.403	1.345	.276	.082

Legend: DL – dominant leg; NL – **non-dominant** leg; F – testing criteria level; p – level of statistical significance; η^2 – Eta squared.

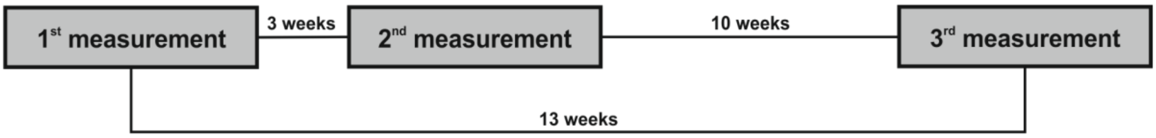

Figure 1. Isokinetic strength measurements during the different phases of the training process.

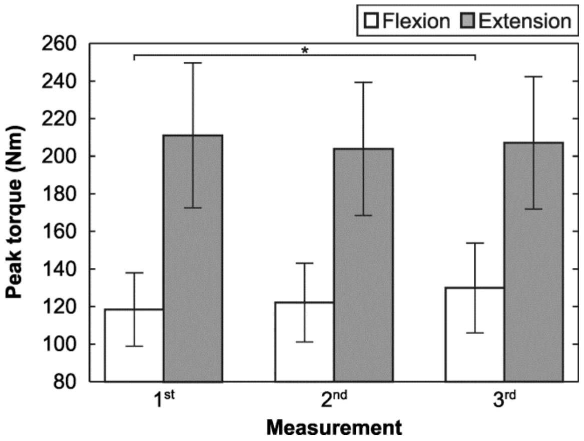

Figure 2. PT values (mean and standard deviation) of dominant leg for flexion and extension at $60°\cdot s^{-1}$ for individual measurements (p<.05*).

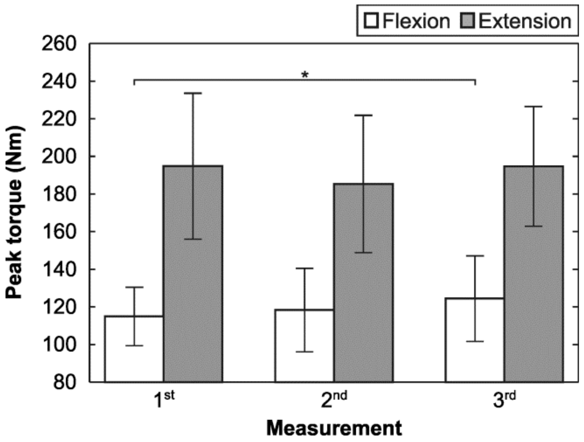

Figure 3. PT values (mean and standard deviation) of **non-dominant** leg for flexion and extension at $60°\cdot s^{-1}$ for individual measurements (p<.05*).

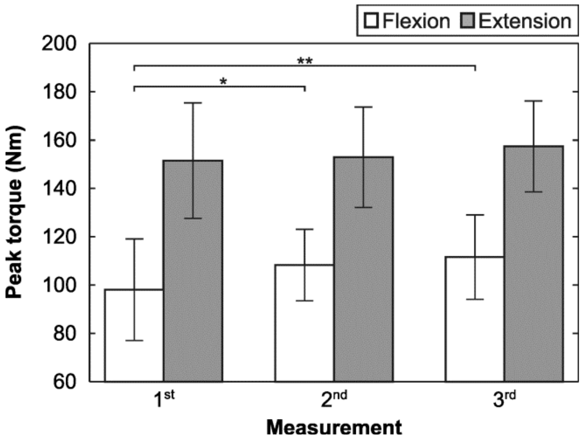

Figure 4. PT values (mean and standard deviation) of dominant leg for flexion and extension at 180°·s^{-1} for individual measurements (p<.05*; p<.01**).

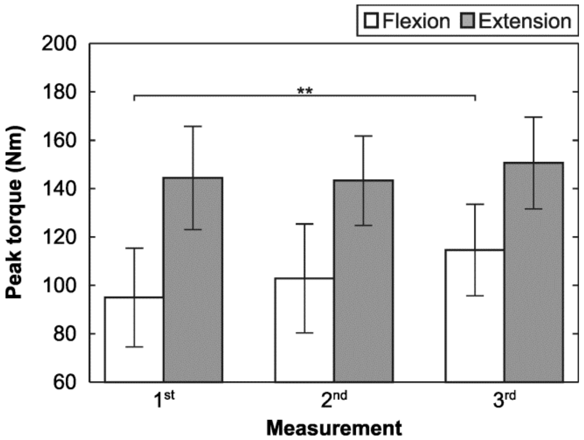

Figure 5. PT values (mean and standard deviation) of **non-dominant** leg for flexion and extension at 180°·s^{-1} for individual measurements (p<.01**).

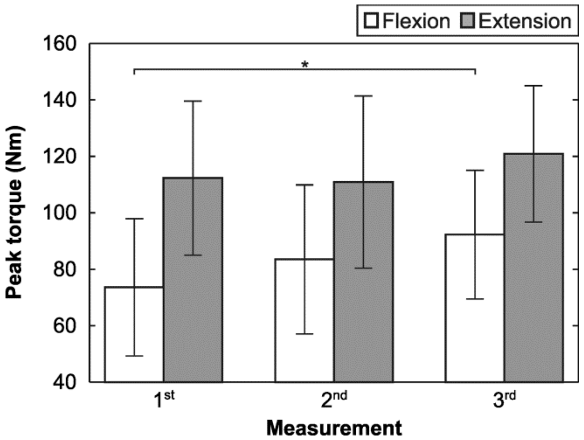

Figure 6. PT values (mean and standard deviation) of dominant leg for flexion and extension at 360°·s^{-1} for individual measurements (p<.05*).

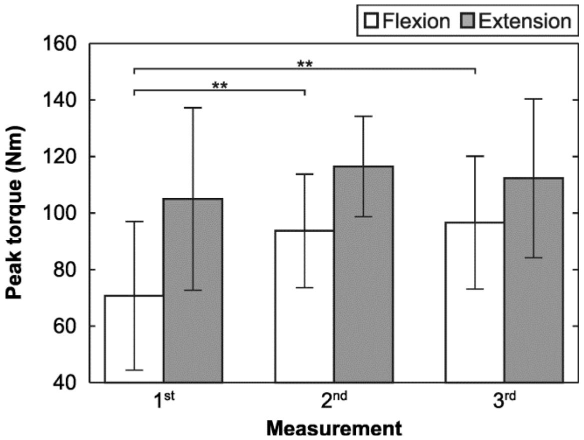

Figure 7. PT values (mean and standard deviation) of **non-dominant** leg for flexion and extension at $360°\cdot s^{-1}$ for individual measurements (p<.01**).