

## SEASONAL VARIATION IN ISOKINETIC PEAK TORQUE IN YOUTH SOCCER PLAYERS

Michal Lehnert<sup>1</sup>, Rudolf Psotta<sup>1</sup>, Petr Chvojka<sup>1</sup> and Mark De Ste Croix<sup>2</sup>

<sup>1</sup>Palacký University in Olomouc; Faculty of Physical Culture, Olomouc, Czech Republic

<sup>2</sup>University of Gloucestershire, School of Sport and Exercise, Gloucester, United Kingdom

Original scientific paper

UDC: 796.012.4:612.73:796.332

### 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  $16.7\pm 0.7$ ) 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  $60^\circ\cdot s^{-1}$ ,  $180^\circ\cdot s^{-1}$ ,  $360^\circ\cdot s^{-1}$  in a sitting position. The testing range of motion was set from  $10-90^\circ$  of knee flexion. Players performed a set of six maximal repetitions for both the 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 the dominant ( $180^\circ\cdot s^{-1}$ ;  $p=.033$ ) and non-dominant legs ( $360^\circ\cdot s^{-1}$ ;  $p=.004$ ). A significant increase was also found between the first and the third session for both limbs during the 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 the 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 non-specific 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 ( $500^{\circ}\cdot\text{s}^{-1}$ ).

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  $16.7\pm 0.7$  years; body height  $177.6\pm 6.0$  cm; body weight  $66.5\pm 9.1$  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  $100^{\circ}$ . 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 hand-grips located at the side of the seat during all testing efforts.

Angular velocities of  $60^{\circ}\cdot\text{s}^{-1}$ ,  $180^{\circ}\cdot\text{s}^{-1}$  and  $360^{\circ}\cdot\text{s}^{-1}$  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  $80^{\circ}$  and was set from  $10^{\circ}$ – $90^{\circ}$  of knee flexion (with  $0^{\circ}$  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).

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 value; 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)
<b>Physical fitness training</b>		
Strength and power training	362*	142**
Speed and agility training	370	232
Aerobic training	652	277
<b>Skill-oriented training</b>		
Technical-tactical training	926	645
Game-like training	945	368
<b>Matches</b>	1355	630
<b>Regeneration</b>	445	270
<b>TOTAL</b>	5055	2540

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

## 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* Scheffé'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).

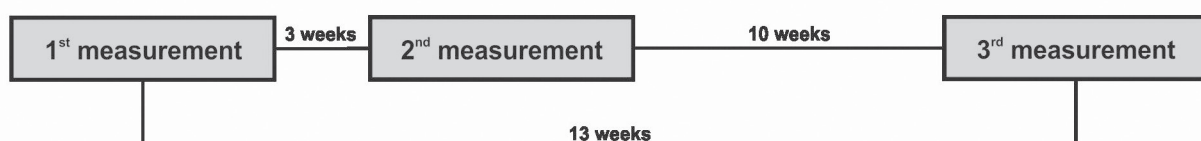


Figure 1. Isokinetic strength measurements during the different phases of the training process.

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

Parameter	1 <sup>st</sup> measurement		2 <sup>nd</sup> measurement		3 <sup>rd</sup> 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 ( $^{\circ}\cdot\text{s}^{-1}$ ); 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	$\eta^2$	F	p	$\eta^2$
DL $60^{\circ}\cdot\text{s}^{-1}$	4.363	.022	.225	0.877	.423	.056
NL $60^{\circ}\cdot\text{s}^{-1}$	3.912	.031	.207	0.693	.508	.044
DL $180^{\circ}\cdot\text{s}^{-1}$	7.378	.002	.330	1.289	.290	.079
NL $180^{\circ}\cdot\text{s}^{-1}$	9.204	<.001	.380	1.129	.337	.070
DL $360^{\circ}\cdot\text{s}^{-1}$	4.505	.019	.231	2.268	.121	.131
NL $360^{\circ}\cdot\text{s}^{-1}$	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;  $\eta^2$  – Eta squared.

*Post-hoc* analysis (Figures 2–7) revealed a statistically significant increase in PT from the 1<sup>st</sup> to the 2<sup>nd</sup> measurement but only for the DL flexion PT at  $180^{\circ}\cdot\text{s}^{-1}$  and NL flexion PT at  $360^{\circ}\cdot\text{s}^{-1}$  (Figures 4, 7). However, in the 3<sup>rd</sup> measurement knee flexion PT was significantly higher compared to the 1<sup>st</sup> 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. During knee flexion at all the angular velocities PT gradually increased from the 1<sup>st</sup> to the 3<sup>rd</sup> measurement for both lower extremities (Figures 2–7). During knee extension of DL and NL at the angular velocity of  $60^{\circ}\cdot\text{s}^{-1}$ , a PT decrease was observed in the 2<sup>nd</sup> measurement followed by an increase in the 3<sup>rd</sup> measurement. A similar trend was observed for NL extension at  $180^{\circ}\cdot\text{s}^{-1}$ . On the contrary, PT of DL extensors at  $180^{\circ}\cdot\text{s}^{-1}$  slightly increased from the 1<sup>st</sup> to the 3<sup>rd</sup> measurement. At  $360^{\circ}\cdot\text{s}^{-1}$  a decrease

for DL extensors was observed from the 1<sup>st</sup> to the 2<sup>nd</sup> measurement followed by an increase in the 3<sup>rd</sup>

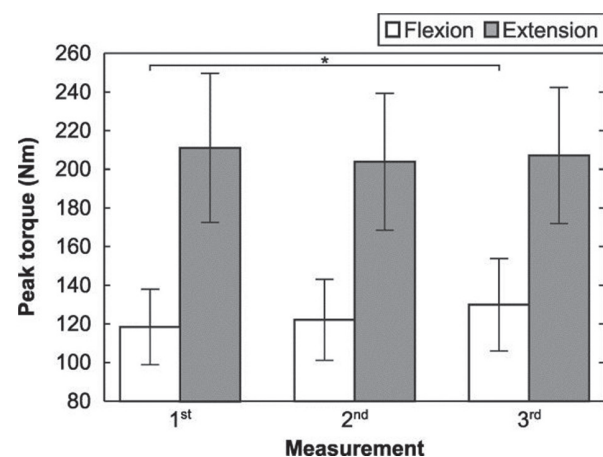


Figure 2. PT values (mean and standard deviation) of dominant leg for flexion and extension at  $60^{\circ}\cdot\text{s}^{-1}$  for individual measurements ( $p < .05^*$ ).

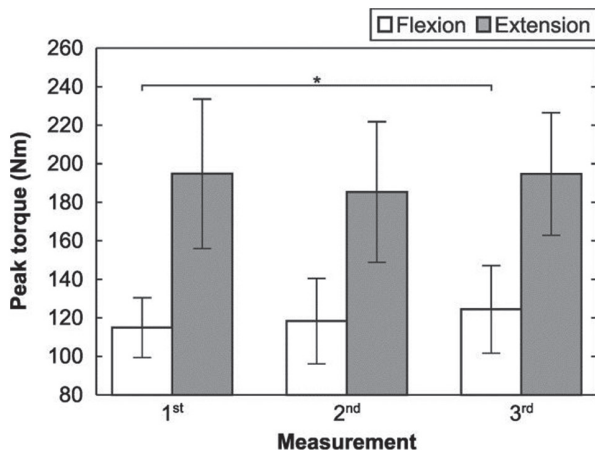


Figure 3. PT values (mean and standard deviation) of non-dominant leg for flexion and extension at 60°·s<sup>-1</sup> for individual measurements ( $p < .05^*$ ).

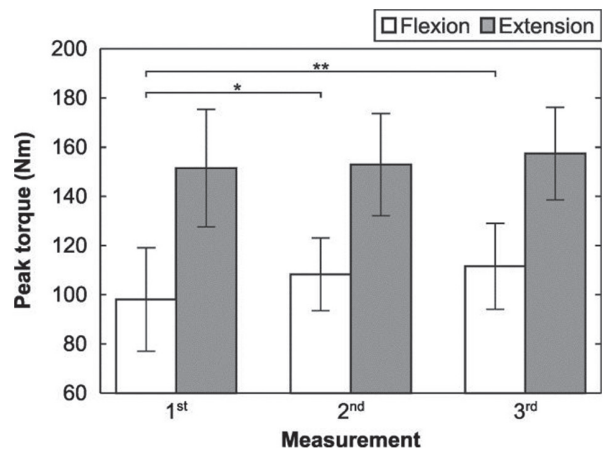


Figure 4. PT values (mean and standard deviation) of dominant leg for flexion and extension at 180°·s<sup>-1</sup> for individual measurements ( $p < .05^*$ ;  $p < .01^{**}$ ).

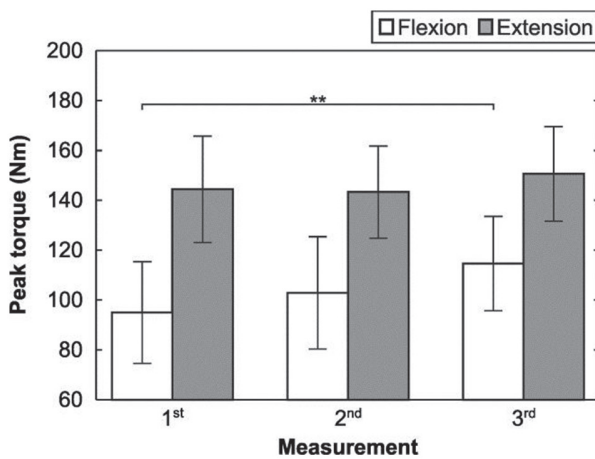


Figure 5. PT values (mean and standard deviation) of non-dominant leg for flexion and extension at 180°·s<sup>-1</sup> for individual measurements ( $p < .01^{**}$ ).

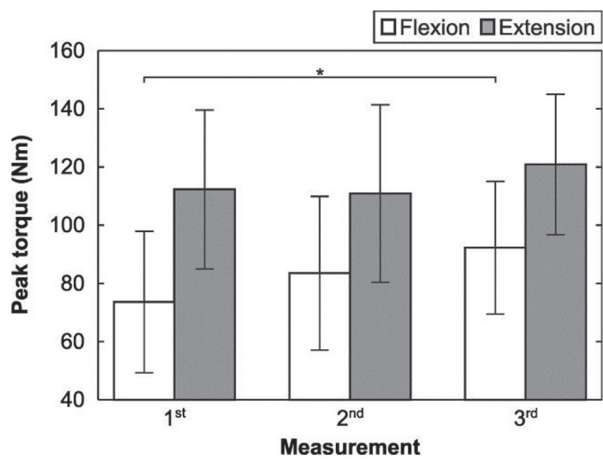


Figure 6. PT values (mean and standard deviation) of dominant leg for flexion and extension at 360°·s<sup>-1</sup> for individual measurements ( $p < .05^*$ ).

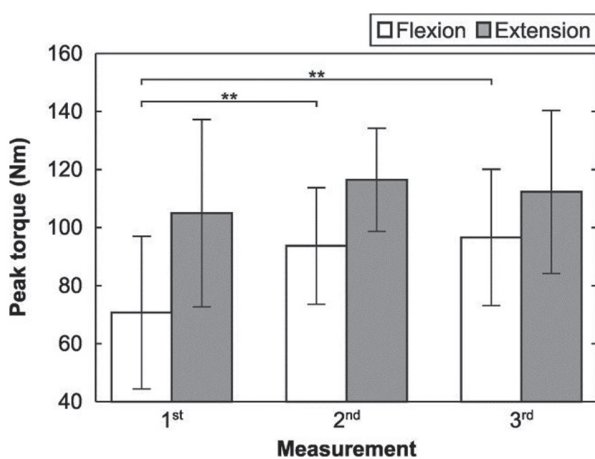


Figure 7. PT values (mean and standard deviation) of non-dominant leg for flexion and extension at 360°·s<sup>-1</sup> for individual measurements ( $p < .01^{**}$ ).

measurement, whereas the trend for NL extensors was the opposite (an increase in PT from the 1<sup>st</sup> to the 2<sup>nd</sup> measurement and then a decrease in the 3<sup>rd</sup> 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  $60^{\circ}\cdot\text{s}^{-1}$ : DL  $151\pm 31$ – $211.1\pm 38$  Nm; NL  $153.1\pm 25$ – $199\pm 38$  Nm; flexion PT at  $60^{\circ}\cdot\text{s}^{-1}$ : DL  $84.1\pm 17$ – $129.9\pm 23$  Nm; NL  $95.3\pm 72$ – $124.4\pm 22$  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 the 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  $60^{\circ}\cdot\text{s}^{-1}$ ,  $180^{\circ}\cdot\text{s}^{-1}$  and  $360^{\circ}\cdot\text{s}^{-1}$  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  $180^{\circ}\cdot\text{s}^{-1}$

for DL and at  $360^{\circ}\cdot\text{s}^{-1}$  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 effects of fatigue 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  $360^{\circ}\cdot\text{s}^{-1}$ , 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  $60^{\circ}\cdot\text{s}^{-1}$  in the 2<sup>nd</sup> 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  $60^{\circ}\cdot\text{s}^{-1}$  from the post-season to the beginning of competitive season (Figure 2 and 3). At movement velocity of  $180^{\circ}\cdot\text{s}^{-1}$  and  $360^{\circ}\cdot\text{s}^{-1}$  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  $60^{\circ}\cdot\text{s}^{-1}$  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 explosive activities of soccer players (post-activation potentiation) (Behm & 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, so many applied workouts are not compatible. Therefore, the training effect is reduced and the ability to maintain peak performance is limited, thus not reflecting 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 (1<sup>st</sup> after season, 2<sup>nd</sup> after post-season, 3<sup>rd</sup> after pre-season) and the authors also reported stagnation and even a small decrease in extensor PT at velocities of  $60^{\circ}\cdot\text{s}^{-1}$  and  $180^{\circ}\cdot\text{s}^{-1}$  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 suggested 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 the 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 if the increase in injury risk is to be avoided and performance optimized.

## References

- Asking, C., Karlsson, J., & Thorstensson, A. (2003). Hamstring injury in elite soccer players after pre-season strength training with eccentric overload. *Scandinavian Journal of Medicine & Science in Sports*, 13(4), 244–250.
- Baltzopoulos, V., & Brodie, D.A. (1989). Isokinetic dynamometry: Applications and limitations. *Sports Medicine*, 8(2), 101–116.
- Behm, D.G., & Sale, D.G. (1993). Intended rather than actual movement velocity determines velocity-specific training response. *European Journal of Applied Physiology*, 74(1), 359–368.
- Bradley, P.S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krstrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences*, 27(2), 159–168.
- Bravo, D.F., Impellizzery, F.M., Rampinini, E., Castagna, C., Bishop, D., & Wisloff, U. (2008). Sprint vs. interval training in football. *International Journal of Sports Medicine*, 29(8), 668–674.
- Brito, J., Figueiredo, P., Fernandes, L., Seabra, A., Soares, J., Krstrup, P., & Rebelo, A. (2010). Isokinetic strength effects of FIFA's "The 11+" injury prevention training programme. *Isokinetics and Exercise Science*, 18(4), 211–215.
- Cerrah, A.O., Gungor, E.O., Soylu, A.R., Ertan, H., Lees, A., & Bayrak, C. (2011). Muscular activation patterns during the soccer in-step kick. *Isokinetics and Exercise Science*, 19(3), 181–190.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum.
- De Ste Croix, M.B., Deighan, M.A., & Armstrong, N. (2003). Assessment and interpretation of isokinetic muscle strength during growth and maturation. *Sports Medicine*, 33(10), 727–744.
- Dirnberger, J., Kösters, A., & Müller, E. (2012). Concentric and eccentric isokinetic knee extension: A reproducibility study using the IsoMed 2000-dynamometer. *Isokinetics and Exercise Science*, 20(1), 31–35.
- Eniseler, N., Şahan, Ç., Vurgun, H., & Mavi, H.F. (2012). Isokinetic strength responses to season-long training and competition in Turkish elite soccer players. *Journal of Human Kinetics*, 31, 159–168.
- Fleck, S.J., & Kraemer, W.J. (2004). *Designing resistance training programs*. Champaign, IL: Human Kinetics.
- Folland, J.P., & Williams, A.G. (2007). The adaptations to strength training (morphological and neurological contributions to increased strength). *Sports Medicine*, 37(2), 145–168.
- Forbes, H.A., Sutcliffe, S., Lovell, A., McNaughton, L.R., & Siegler, J.C. (2009). Isokinetic thigh muscle ratio in youth football: Effect of age and dominance. *International Journal of Sports Medicine*, 30(8), 602–606.
- Gioftsidou, A., Beneka, A., Malliou, P., Pafis, G., & Godolias, G. (2006). Soccer players' muscular imbalances: Restoration with an isokinetic strength training program. *Perceptual & Motor Skills*, 103(1), 151–159.
- Gioftsidou, A., Ispirlidis, I., Pafis, G., Malliou, P., Bikos, C., & Godolias, G. (2008). Isokinetic strength training program for muscular imbalances in professional soccer players. *Sport Sciences for Health*, 2(3), 101–105.
- Gür, H., Akova, B., Pündük, Z., & Küçüköğlü, S. (1999). Effects of age on the reciprocal peak torque ratios during knee muscle contractions in elite soccer players. *Scandinavian Journal of Medicine & Science in Sports*, 9(2), 81–87.

- Hughes, G., & Watkins, J. (2006). A risk-factor model for anterior cruciate ligament injury. *Sports Medicine*, 36(5), 411–428.
- Iga, J., George, K., Lees, A., & Reilly, T. (2009). Cross-sectional investigation of indices of isokinetic leg strength in youth soccer players and untrained individuals. *Scandinavian Journal of Medicine & Science in Sports*, 19(5), 714–719.
- Issurin, V.B. (2010). New horizons for the methodology and physiology of training periodization. *Sports Medicine*, 40(3), 189–206.
- Kellis, S., Gerodimos, V., Kellis, E., & Manou, V. (2001). Bilateral isokinetic concentric and eccentric strength profile of the knee extensors and flexors in young soccer players. *Isokinetics and Exercise Science*, 9(1), 31–39.
- Lehance, C., Binet, J., Bury, T., & Croisier, J.L. (2009). Muscular strength, functional performances and injury risk in professional and junior elite soccer players. *Scandinavian Journal of Medicine & Science in Sport*, 19(2), 243–251.
- Lehnert, M., Psotta, R., & Botek, Z. (2012). A comparison of effects of high-resistance and plyometric training on adolescent soccer players. *Gazetta Medica Italiana Archivio per le Scienze Mediche*, 171(5), 567–576.
- Lehnert, M., Urban, J., Prochazka, J., & Psotta, R. (2011). Isokinetic strength of knee flexors and extensors of adolescent soccer players and its changes based on movement speed and age. *Acta Universitatis Palackianae Olomucensis. Gymnica*, 41(2), 45–53.
- Malliou, P., Ispirlidis, I., Beneka, A., Taxildaris, K., & Godolias, G. (2003). Vertical jump and knee extensors isokinetic performance in professional soccer players related to the phase of the training period. *Isokinetics and Exercise Science*, 11, 165–169.
- Maly, T., Zahalka, L., & Mala, L. (2013). Isokinetic strength characteristics and norms in the best Czech soccer players of U16 category. *Medicine & Science in Sports & Exercise*, 45(5), 167–168.
- Maly, T., Zahalka, F., & Mala, L. (2011). Differences between isokinetic strength characteristics of more and less successful professional soccer teams. *Journal of Physical Education and Sport*, 11(3), 306–312.
- Morrissey, M.C., Harman, E.A., & Johnson, M.J. (1995). Resistance training modes: Specificity and effectiveness. *Medicine & Science in Sports & Exercise*, 27(5), 648–660.
- Mujika, I., & Padilla, S. (2000a). Detraining: Loss of training-induced physiological and performance adaptations. Part I. *Sports Medicine*, 30(2), 79–87.
- Mujika, I., & Padilla, S. (2000b). Detraining: Loss of training-induced physiological and performance adaptations. Part II. *Sports Medicine*, 30(3), 145–154.
- Newman, M.A., Tarpenning, K.M., & Marino, F.E. (2004). Relationships between isokinetic knee strength, single sprint performance, and repeated-sprint ability in football players. *Journal of Strength and Conditioning Research*, 18, 867–872.
- Proske, U., Morgan, D.L., Brockett, C.L., & Percival, P. (2004). Identifying athletes at risk of hamstrings strains and how to protect them. *Clinical and Experimental Pharmacology & Physiology*, 31, 546–550.
- Ratamess, N.A. (2008). Adaptations to anaerobic training programs. In T. R. Baechele & W.R. Earle (Eds.), *Essentials of strength training and conditioning* (pp. 93–120). Champaign, IL: Human Kinetics.
- Sangnier, S., & Tourny-Chollet, C. (2007). Comparison of the decrease in strength between hamstring and quadriceps during isokinetic fatigue testing in semiprofessional soccer players. *International Journal of Sports Medicine* 28(11), 952–957.
- Schmid, S., & Alejo, B. (2002). *Complete conditioning for soccer*. Champaign, IL: Human Kinetics.
- StatSoft, Inc. (2010). *Statistica 10* [Computer Software]. Tulsa, OK: StatSoft.
- Steffen, K., Bakka, H.M., Myklebust, G., & Bahr, R. (2008). Performance aspects of an injury prevention program: A ten-week intervention in adolescent female football players. *Scandinavian Journal of Medicine & Science in Sports*, 18(5), 596–604.
- Stølen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer. *Sports Medicine*, 35(6), 501–536.
- Verheijen, R. (1998). *Conditioning for soccer*. Spring City: Reedswain.
- Wathen, D., Baechele, T.R., & Earle, R.W. (2008). Periodization. In T. R. Baechele, & W. R. Earle (Eds.), *Essentials of strength training and conditioning* (pp. 507–522). Champaign, IL: Human Kinetics.
- Wirth, K., & Schmidbleicher, D. (2007). Periodisierung im Schnellkrafttraining. [Periodization in power training. In German.] *Leistungssport*, 37(2), 16–20.
- Westing, S.H., Seger, J., Karlson, E., & Ekblom, B. (1988). Eccentric and concentric torque-velocity characteristics of the quadriceps femoris in man. *European Journal of Applied Physiology*, 58, 100–104.
- Wrigley, T.W. (2000). Assessment for football: soccer, Australian rules, and American. In L.E. Brown (Ed.), *Isokinetics in human performance* (pp. 407–428). Champaign, IL: Human Kinetics.



## VARIJACIJE TIJEKOM SEZONE U IZOKINETIČKOM VRŠNOM MOMENTU SILE KOD MLADIH NOGOMETAŠA

Cilj je ovog istraživanja bio utvrditi varijacije tijekom sezone u snazi pregibača i opružača potkoljenice vrhunskih treniranih mladih nogometaša. Igrači ( $n=16$ ; dob  $16,7\pm 0,7$ ) su testirani na kraju natjecateljske sezone, na početku prijelaznog perioda te tijekom šestog tjedna nove natjecateljske sezone. Izokinetički koncentrični vršni moment sile mjerio se pri brzinama od  $60^\circ/s$ ,  $180^\circ/s$  i  $360^\circ/s$  u sjedećem položaju ispitanika. Opseg pokreta se tijekom testiranja kretao od  $10$  do  $90^\circ$  fleksije koljena. Igrači su izveli seriju od šest maksimalnih ponavljanja prvo dominantnom, a onda i nedominantnom nogom. Prosječne vrijednosti vršnog momenta sile značajno su se mijenjale tijekom promatranih perioda. Značajne razlike ( $p<0,05$ ) u snazi pregibača potkoljenice zabilježene su između sva tri mje-

renja pri sve tri brzine izvedonja. *Post hoc* test je također potvrdio značajno povećanje snage pregibača potkoljenice između prvoga i drugog mjerenja za dominantnu ( $180^\circ/s$ ;  $p=0,033$ ) i nedominantnu ( $360^\circ/s$ ;  $p=0,004$ ) nogu. Značajno povećanje vršnog momenta sile pregibača potkoljenice obje noge pri svim brzinama također je zabilježeno između drugoga i trećeg mjerenja. Rezultati pokazuju da vršni moment sile pregibača i opružača potkoljenice različito varira kod treniranih mladih nogometaša ovisno o mišićnoj grupi i brzini pokreta, sa statističkom značajnošću promjena samo za pregibače potkoljenice.

**Ključne riječi:** opružači potkoljenice, pregibači potkoljenice, periodizacija, snaga, trening

Submitted: May 31, 2013

Accepted: November 15, 2013

Correspondence to:

Assoc. Prof. Michal Lehnert, Ph.D.  
Faculty of Physical Culture Palacký  
University in Olomouc  
Tr. Miru 115, 771 11 Olomouc  
Czech Republic  
Phone: +420 585636105  
Fax: +420 585 412 899  
E-mail: michal.lehnert@upol.cz