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INFLUENCE OF CORE STRENGTH TRAINING ON PEAK MUSCLE TORQUE OF QUADRICEPS AND HAMSTRING IN YOUNG SOCCER PLAYERS

VPLIV TRENINGA MOČI NA MIŠIČNI MOMENT KVADRICEPSA IN HAMSTRINGA PRI MLADIH NOGOMETAŠIH

ABSTRACT

The purpose of the present study was to investigate the effect of eight week core strength training (CST) on quadriceps and hamstring muscle strength and H/Q ratio. The study included a total of 20 young soccer players, 10 in the experimental group (EG) and 10 in the control group (CG). Isokinetic knee strength measurements at angular velocities of 60°sec^{-1}, 180°sec^{-1} and 240°sec^{-1} were performed on the subjects. Independent sample t-test and 2x2 ANOVA test were used for statistical analysis. No significance was found between the pre-test results of both EG and CG ($p>0.05$). In post-test results, a difference was found in favour of EG group in RPM 60^{o} EX value ($p<0.05$). When the pre-test and post-test results of the groups were compared separately, a significant difference was found in RPM 60^{o} EX, LPM 180^{o} EX and LPM 240^{o} EX parameters in EG ($p<0.05$). A significant progress was found in LPM 180^{o} EX, LPM 180^{o} FLX and LPM 240^{o} FLX values in CG ($p<0.05$). It was found that CST applied on young soccer players affected knee isokinetic strength in different velocity and this effect caused significance especially in different angular speeds of EX phase. In addition, although significant progress was not observed in all parameters in EG after CST, it was found that there weren't decreases in any parameters and at least strength was maintained.

Keywords: isokinetic knee strength; soccer player; core exercises; H/Q ratio

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IZVLEČEK

Namen študije je bil raziskati učinek osem tedenskega treninga moči (TM) na kvadriceps (Q) in stegenske mišice (H) ter razmerje H / Q. V študiji je sodelovalo 20 mladih nogometašev, od tega 10 v eksperimentalni skupini (EG) in 10 v kontrolni skupini (CG). Opravili smo izokinetične meritve moči kolena pri kotnih hitrostih 60°s^{-1}, 180°s^{-1} in 240°s^{-1}. Za ugotavljanje razlik med skupinami smo naredili t-test za neodvisne vzorce in 2X2 analizo variance (2x2 ANOVA). Pre-test ni pokazal statistično značilnih razlik med EG in CG ($p> 0,05$). Post-test je pokazal, da obstajajo značilne razlike v korist EG za kar RPM 60^{o} EX ($p <0,05$). Ko smo ločeno primerjali rezultate pre- in post-testa obeh skupin, smo ugotovili značilne razlike v parametrih RPM 60^{o} EX, LPM 180^{o} EX in LPM 240^{o} EX v EG ($p <0,05$). Znaten napredek je bil ugotovljen pri vrednostih LPM 180^{o} EX, LPM 180^{o} FLX in LPM 240^{o} FLX v CG ($p <0,05$). Ugotovljeno je bilo, da je trening moči, ki se uporablja pri mladih nogometaših, z različno hitrostjo značilno vplival na izokinetično moč kolena.

Ključne besede: izokinetična moč kolena; nogometni igralec; osnovne vaje; razmerje H/Q

INTRODUCTION

Soccer, which is one of the most popular sport branches of our day, is a game in which top level physical fitness and condition should be shown due to high number and intensity of matches and intense training it includes (Cometti et al., 2001). In addition, the player's position and league and even the tactical and technical characteristics of the game played have a great significance for developing and advancing a soccer player's performance (Little & Alun, 2005; Jovanovic, Sporis, Omrcen & Fiorentini, 2011). All these components have increased injury rates and the tendency for injury in players, and for this reason, especially clubs in top level leagues include teams consisting of experts such as conditioner and physiotherapist in addition to trainers in their teams. These teams apply special and specific methods to prevent injuries, to follow and to maintain soccer players' conditions.

Core strength training (CST) has a great significance for physiotherapists, trainers and professions interested in rehabilitation (Akuthota & Nadler, 2004; Yu & Lee, 2012). Researchers have reported that CST applied on different sample groups and with different methods have positive influence on core stabilization (Hibbs, Thompson, French & Wrigley, 2008), athletic performance (Sever & Zorba, 2018), movement and psychomotor development (Okada, Huxel & Nesser, 2011; Özmen & Aydoğmuş, 2016), and posture control. At the same time, researchers have shown that a strong core area has positive influence on strength transfer that develops between lower extremity (Baker, 2000), trunk (Behm et al., 2005) and upper extremity (Foran, 2001), while a weak core area can lead to low athletic performance, underdeveloped muscle group formation and high risk injury development (Nesser, Huxel, Tincher & Okada, 2005). Because of all these reasons, CST has become a popularly used method today by conditioners and trainers in order to increase athletic performance and to minimize the risk of injury. While studies which examined the effects of CST programs prepared in accordance with different branches on performance parameters have found positive development in some branches (Stanton, Reaburn & Humphries, 2004; Tse, McManus & Masters, 2005), others have not found any development (Scibek, 1999). There are studies which have shown that CST applied on soccer players have positive effects on athletic performance, some motoric characteristics and core stabilization (Lee & Han, 2016; Sever & Zorba, 2018). It is also known that today's researchers apply different types of CST in order to find out the possible risk factors which cause injuries in team and individual sports in which muscle asymmetries and muscle strength imbalance in lower extremity muscles have great significance, such as soccer (Iacono, Padulo & Ayalon, 2016).

Based on the existing literature information, although there are studies in which the effects of CST on performance parameters in different branches are examined, the number of studies which examine the effects of CST on isokinetic knee extension (EX) and flexion (FLX) strength, especially in soccer players, is still limited. In particular, there are no studies investigating the effect of CST on isokinetic knee strength in soccer players. Based on all this information, the aim of the present study is to analyze the effects of eight-week CST in different angular velocity on isokinetic knee strength and Hamstring (H)/ Quadriceps (Q) H/Q ratio in young soccer players. In addition, the present study is the first study to examine the effects of CST applied to young soccer players on isokinetic knee strength. The study hypothesizes that eight-week CST will have positive effects on knee EX and FLEX strength at different angular velocity.

METHODS

Experimental design

Eight weeks of CST was implemented in the present study. The effects of CST were found with a test-retest design including a control group (CG). 3 sessions were made with the subjects. In the first of these sessions, the measurements and the CST exercise program to be included in the experiment were introduced to the Experimental Group (EG). Pre-test measurements for isokinetic knee strength were performed for CG and EG groups in the second session. In the third session, isokinetic knee strength post-tests were completed. The measurements were made at the same time on each day between 14:00 and 16:00. The subjects were not allowed to do exercise or high-intensity physical activity before sessions. Between the pre- and post-tests, eight-week CST program was implemented in the EG and the subjects continued in their usual sport training routine. Meanwhile, CG subjects were told only to take part in their usual training routine. The present study was designed and implemented in accordance with the Declaration of Helsinki (World Medical Association, 2013). Written consent from subjects and ethical approval from local ethical committee were received.

Subjects

Twenty young soccer players were grouped in two formed the subjects of the present study. There were 10 soccer players (age 15.60 ± 0.55) in the first group, which was the EG, while there were also 10 soccer players (age 15.60 ± 0.55) in the second group, which was the CG.

All of the subjects in both groups were actively playing soccer in Turkish Football Federation's U17 league and in the same team.

Determination of descriptive information

Height, weight and BMI parameters of the subjects were found by using a Gaia 359 Plus BodyPass analyser. The device was introduced to the subjects before making measurements during which they were asked to be as quiet and immobile as possible. In order to help the subjects understand how the test worked, it was demonstrated by an individual on the analyzer before the tests. Following this, the subjects' height (cm), weight (kg) and BMI values were recorded while they were bare footed, wearing a t-shirt and shorts. Age, position and training ages of the subjects were obtained from the personal information form given to subjects.

Isokinetic knee strength testing

$60°sec^{-1}$, $180°sec^{-1}$ and $240°sec^{-1}$ were determined as the peak torque angular velocity the subjects were to show in knee extension and flexion moves. Computer controlled isokinetic dynamometer (Humac Norm Testing and Rehabilitation System, CSMI, USA) was used to implement the tests. In order to implement each test at the predetermined angles, the subjects were verbally told to take into consideration the resting intervals in line with the fixed protocol of the dynamometer. After the determination of resting intervals, five maximum efforts were shown by the subjects and peak torque value was accepted as the highest value shown during five tries of all angular velocities. Before the actual test, three practice repetitions of all angular velocities were made to help the subjects adapt and to protect them from injuries and the test was started following a 30 seconds of rest. Throughout the whole test, the subjects were verbally encouraged about basic push/pull, the number of remaining repetitions and also to help them reach the highest peak torque (PT) values. All the subjects were asked to use their knee strength in the maximal level for a positive test and to get maximal results before starting the test (Davies & Dalsky, 1997). PT values were recorded as Newton (Nm) in all angular velocities. Isokinetic dynamometer was calibrated as advised by CSMI before starting the isokinetic knee strength test (2003).

CST program

CST protocol was not applied to CG subjects. They were told to follow their respective sport training routine. In addition to eight-week CST program, the EG subjects continued in their usual sport training routine. CST was applied three times per week and continued with the same

layout for 8 weeks. The layout of the CST program was as follows: 1) One arm/leg plank balance (10 right - 10 left) repetitions, (2) Side plank, triangle crunches (right side, left side) each 20 seconds, (3) plank (Elbow plank) for 30 seconds, (4) Reverse elbow plank for 30 seconds, (5) cobra exercise for 30 seconds, (6) (Side plank, triangle crunches) 30 seconds, (7) walk over (Backbends exercise) for 30 seconds, (8) cross sit-up for 30 seconds, (9) sit-up, 20 repetitions, (10) Feet hard assisted superman exercise, 15 repetitions, (11) hamstring exercise (Push-ups, jump-inside the lines), 6 repetitions. All of the CST moves were made in two sets and there were 60 seconds of rests between sets.

Statistical analyses

SPSS program (SPSS for Windows, version 22.0, SPSS Inc., Chicago, Illinois, USA) was used for statistical analyses. The data were presented as mean and standard deviation. For normality, Shapiro–Wilk test was used, while independent sample t-test was used to compare descriptive statistic for each group. In order to determine the significant effects of the CST on the isokinetic knee strength, two way repeated measures ANOVA was used. Effect sizes were found according to Cohen's d effect size (M2 − M1)⁄SDpooled) in the comparison of paired groups. $p<0.05$ significance level was used to assess the statistical results.

RESULTS

Table 1. Descriptive statistics of subjects

Variables	Group	N	Mean	SD	t	p
Age (year)	**EG**	10	15.60	.55	.000	1.00
	CG	10	15.60	.55		
Height (cm)	**EG**	10	178.20	3.36	0.878	0.406
	CG	10	175.20	6.37		
Weight (kg)	**EG**	10	59.80	3.29	0.090	0.930
	CG	10	59.40	8.76		
BMI (kg/m^2)	**EG**	10	18.73	.59	-.509	0.625
	CG	10	19.28	2.20		

When the descriptive data of the subjects were examined statistically, no significant difference was found between EG and CG in terms of age, height, weight and BMI parameters ($p>0.05$).

According to these results, it was found that both groups had a homogeneous distribution in terms of descriptive data (Table 1).

Table 2. Differences in isokinetic knee strengths between EG and CG in pre and post test

		EG (n: 10)		CG (n: 10)	
Variables		**Mean±SD**	**E.S**	**Mean±SD**	**E.S**
RPM 60º EX (Nm)	Pre-test	217.20±18.73	0.76	212.00±24.07	-0.54
	Post-test	232.20±20.55†,**		199.60±20.96†	
RPM 180º EX (Nm)	Pre-test	135.20±14.41	0.01	121.00±22.06	0.17
	Post-test	135.00±25.95		124.20±15.40	
RPM 240º EX (Nm)	Pre-test	117.40±11.67	0.42	112.20±18.40	-0.54
	Post-test	123.80±17.81		103.40±13.20	
LPM 60º EX (Nm)	Pre-test	203.60±27.27	0,40	194.60±24.15	0.13
	Post-test	215.40±31.42		191.80±18.57	
LPM 180º EX (Nm)	Pre-test	114.60±15.44	1.17	117.80±28.65	0.48
	Post-test	138.80±24.66†		130.00±21.71†	
LPM 240º EX (Nm)	Pre-test	93.20±16.12	1.67	105.80±22.73	0.32
	Post-test	121.40±17.52†		112.40±18.39	
RPM 60º FLX (Nm)	Pre-test	120.00±19.25	0.11	113.60±29.69	0.38
	Post-test	122.20±17.78		122.60±16.32	
RPM 180º FLX (Nm)	Pre-test	76.80±17.19	0,02	75.80±16.96	0.61
	Post-test	77.20±16.71		83.60±5.68	
RPM 240º FLX (Nm)	Pre-test	66.80±22.79	0.37	73.00±10.12	0.06
	Post-test	73.20±7.15		73.60±8.50	
LPM 60º FLX (Nm)	Pre-test	106.60±19.65	0.65	101.80±13.79	0.17
	Post-test	117.40±12.72		103.80±9.03	
LPM 180º FLX (Nm)	Pre-test	73.00±21.78	0.56	74.60±8.50	1.03
	Post-test	83.00±12.17		84.80±11.12†	
LPM 240º FLX (Nm)	Pre-test	63.40±24.17	0.60	68.60±10.06	0.91
	Post-test	74.20±7.12		77.20±8.79†	

† significant difference between pre-test and post-test;* significant difference in pre-test between EG and CG;**significant difference in post-test between EG and CG; SD standard deviation; E.S. effect size; RPM right peak muscle torque; LPM left peak muscle torque; EX extension; FLX flexion

Pre-test and post-test isokinetic knee strength results of EG and CG groups were compared statistically in Table 2. According to these results, when pre-test results of both groups were compared, no statistical significance was found ($p>0.05$). When post-test results were compared, a significance was found in RPM 60º EX value, in favour of EG ($p<0.05$). When the

pre-test and post-test results of the groups were compared separately, a positive statistically significant difference was found in RPM 60º EX, LPM 180º EX and LPM 240º EX parameters in EG ($p<0.05$). In CG, a positive and statistically significant progress was found in LPM 180º EX, LPM 180º FLX and LPM 240º FLX values ($p<0.05$). However, a decrease was found in RPM 60º EX and RPM 240º EX parameters in CG between pre-test and post-test and this decrease was found to cause a statistically significant result in RPM 60º EX parameter ($p<0.05$) (Table 2).

Table 3. Differences in H/Q ratio between EG and CG in pre-test and post-test

		EG (n: 10)		CG (n: 10)	
Variables		**Mean±SD**	**E.S**	**Mean±SD**	**E.S**
RPM 60º (%)	Pre-test	55.20±7.01	0.26	53.20±9.99	0.95
	Post-test	53.00±9.30		61.80±7.91†	
RPM 180º (%)	Pre-test	56.40±9.86	0.07	62.80±10.84	0.52
	Post-test	57.00±6.63		67.80±7.85**	
RPM 240º (%)	Pre-test	56.00±14.61	0.30	65.40±8.87	0.71
	Post-test	59.40±6.42		71.60±8.38**	
LPM 60º (%)	Pre-test	52.60±6.61	0,37	52.60±5.72	0.03
	Post-test	55.00±6.16		52.40±6.35	
LPM 180º (%)	Pre-test	63.00±16.00	0,19	65.20±11.88	0.07
	Post-test	60.60±7.09		66.00±7.78	
LPM 240º (%)	Pre-test	67.80±22.98	0,31	66.20±10.25	0,34
	Post-test	62.20±10.13		70.00±11.92	

† significant difference between pre-test and post-test;* significant difference in pre-test between EG and CG;**significant difference in post-test between EG and CG; SD standard deviation; E.S. effect size; RPM right peak muscle torque; LPM left peak muscle torque; EX extension; FLX flexion

Table 3 shows the comparisons of H/Q ratios in pre and post-tests According to these results, no statistical significance was found in any parameter in EG ($p>0.05$). However, a statistical significance was found in RPM 60º EX value in CG ($p<0.05$).

DISCUSSION

The aim of the present study is to analyze the effects of eight-week CST on isokinetic knee strength of 15-16 years of age soccer players by using different angular velocities. Three major results were found in our study, all of which were found in EG. These are the significant developments found in 60 RPM EX, LPM 180 EX, LPM 240 EX strength. In addition to these

results, it was found that in EG group, CST had a significant effect on all parameters, even if not significant. In CG, while the results showed significant increases in some parameters, most of the isokinetic knee strength parameters showed fixed values or decreases. In terms of H/Q ratio, it was found that CST did not cause any changes in H/Q ratio. The results of the present study enabled us to get an idea about the effects of CST on isokinetic knee strength and asymmetry and at the same time the neuromuscular control of the lower extremity in young soccer players.

When similarly conducted studies were examined, Iacono et al. (2016) found that six-week CST had positive effects of muscle strength, muscle strength imbalance and asymmetry. In their study, they found 18% and 24% progress in FLX phase in both right and left sides; an increase between 11% and 15% in EX strength, although not significant, and a significant development in H/Q ratios. Lee and Han (2016) found that peculiar complex CST at 60 degrees angular velocity increased EX and FLX strengths approximately with a rate of 8% and 11%. Han et al. (2011) reported that 12-week CST they applied on volleyball players had positive effects on isokinetic knee and hip isokinetic strength. Moreover, Song and Hong (2012) showed that an 8-week CST program had a positive effect on knee extensor and flexor muscular strength in college baseball players. Other studies conducted showed results which support the findings of our present study (Yang, 2014; Kim & Chung, 2009). The researchers reported that the positive effects of CST on isokinetic knee strength and asymmetric ratios was associated with the improvement of neuromuscular control in the lower extremity by ensuring body stabilization, and this caused improvement in strength production with CST, such as "Nordic hamstring", frontal and lateral balance exercises. They stated that CST included special strength exercises and that this situation could directly contribute to the strength development in muscles Q and H (Iacono, Padulo & Ayalon, 2016). Some theories about the relationship between core stability or CST and lower extremity functions, performance and injury were suggested by researchers. The first of these motor activities in the form of postural support must occur before the initiation of voluntary extremity movements. In addition, the support must vary according to the parameters of the planned movement, posture, and the uncertainty about the upcoming tasks (Willson, Dougherty, Ireland & Davis, 2005; Bouisset, 1991).

Asymmetry and imbalance of lower extremity muscles have been the subject of a great number of studies to determine injuries in different team and individual sports and at the same time to find out the potential risk factors (Fousekis, Tsepis & Vagenas, 2010; Jones & Bompouras, 2010). Lower extremity muscle asymmetry is determined with the strength ratios between

Hamstring and Quadriceps muscles, which are the agonist and antagonist of each other, especially for the knee area (Ermiş et al., 2019; Junge et al., 2002). In our study, it was found that CST did not cause any changes in H/Q ratios. However, in CG group, changes were found in H/Q ratios in different angular velocities. When examined in this aspect, it can be seen that CST keeps the ratio in agonist and antagonist knee muscles which do not have asymmetric structure fixed, which means that it minimizes the occurrence of injury rate. When studies in literature which have examined the effects of CST on muscle asymmetry are reviewed, it can be seen that researchers found a high correlation between muscle asymmetry and strength balance and core stabilization (Hewett, Lindenfeld, Riccobene & Noyes, 1999). There are researchers who advocate the thought that especially CST programs will contribute to minimizing hamstring injuries (Mjolsnes et al., 2004). In addition, some studies reported that tendency for injury decreased and some performance parameters developed when CST programs were included in condition programs of soccer players and some team sports (Olse et al., 2005; Soligard, 2008). Similarly, some of the studies conducted show that lower extremity strength adaptation is directly associated with core stabilization (Brito et al., 2010; Daneshjoo, Mokhtar, Rahnama & Yusof, 2012). Similar to the results of the present study, Iacono et al. (2016) found that 6-week CST decreased bilateral flexor and extensor peak torque strength differences or kept stable in some angular velocity in young soccer players. Daneshjoo et al. (2013) found that an injury prevention program which included CST had a positive effect on strength imbalance and muscle asymmetry in flexor and extensor muscles. Actually, researchers found a relation between strength imbalance and injuries, and stated that training interventions aiming to reduce strength deficiencies in young athletes are likely to correlate with lower risk of football injuries. In this context, researchers recommend that muscle imbalances in the thigh can lead to muscle injuries and increased knee laxity (Andrade et al., 2012).

Additionally, significant injury factors for football and other team sports include strength deficits in knee extensors and knee joint instability, muscle imbalances between extensors and flexors of the knee and eccentric strength asymmetry between the lower extremities (Wong, 2005).

CONCLUSION

It was found that CST program developed strength parameters in different angular velocities in young soccer players. This development was significant in some angular velocities and when evaluated in terms of bilateral muscle asymmetry, it was found that the group included in CST program showed positive developments or they kept the initial ratios stable. In this aspect, it was concluded that CST programs included in training programs of coaches will have a positive effect on players' lower extremity strength and that they will contribute to minimizing the risk of injury. It is important for studies to be conducted in the future to examine the effects of CST on lower extremity strength with different contractions and methods to increase the reliability of this program in every aspect.

Declaration of Conflicting Interests

The authors declare no conflict of interest.

REFERECES

Akuthota, V., & Nadler, S.F. (2004). Core strengthening. *Arch Phys Med Rehabil*, 85, 86-92.

Andrade Mdos, S., De Lira, C.B., Koffes, C., Mascarin, N.C., Benedito-Silva, A.A., & Da Silva, A.C. (2012). Isokinetic hamstrings-to-quadriceps peak torque ratio: The influence of sport modality, gender, and angular velocity. *Journal of Sports Sciences*, 30, 547–553.

Baker, D. (2000). Overuse of Swiss ball training to develop core stability or improve sports performance. *Strength and Conditioning Coach*, 8(2), 5-9.

Behm, D.G., Leonard, A.M., Young, W.B., Bonsey, W.A.C., & MacKinnon, S.N. (2005). Trunk muscle electromyographic activity with unstable and unilateral exercises. *J Strength Cond Res*, 19(1), 193-201.

Bouisset, S., (1991). Relationship between postural support and intentional movement: Biomechanical approach. *Arch Int Physiol Biochim Biophys*, 99,77-92.

Brito, J., Figueiredo, P., Fernandes, L., Seabra, A., Soares, J.M., Krustrup, P., & Rebelo, A. (2010). Isokinetic strength effects of FIFA's "The 11+" injury prevention training programme. *Isokinetics and Exercise Sciences*, 18, 211–215.

Cometti.. G, Maffiuletti, A., Pousson, M., Chatard, J.C., & Maffulli N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *International journal of sports medicine*, 22(01), 45-51.

Daneshjoo, A., Mokhtar, A.H., Rahnama, N., & Yusof, A. (2012) The effects of injury preventive warm-up programs on knee strength ratio in young male professional soccer players. *PLoS One*, 7: 50-79.

Daneshjoo, A., Rahnama, N., Mokhtar, A.H., & Yusof, A. (2013). Effectiveness of injury prevention programs on developing quadriceps and hamstrings strength of young male professional soccer players. *Journal of Human Kinetics*, 39, 115–125.

Davies, M.J., & Dalsky, G.P. (1997). Normalizing strength for body size differences in older adults. *Medicine and Science in Sports and Exercise*, 29(5), 713-717.

Dello Iacono, A., Padulo, J., & Ayalon, M. (2016). Core stability training on lower limb balance strength. *Journal of sports sciences*, 34(7), 671-678.

Ermiş, E., Yilmaz, A.K., Kabadayi, M., Bostanci, Ö., & Mayda, M.H. (2019). Bilateral and ipsilateral peak torque of quadriceps and hamstring muscles in elite judokas. *Journal of musculoskeletal & neuronal interactions*, 19(3), 286.

Foran, B. (2001). High-performance sports conditioning. *Human Kinetics*.

Fousekis, K., Tsepis, E., & Vagenas, G. (2010). Lower limb strength in professional soccer players: Profile, asymmetry, and training age. *Journal of Sports Science and Medicine*, 9, 364–373.

Han, D.Y., Kim, K.C., & Hyun, K.S. (2011). Effect of specificity core balance training on isokinetic muscular functions in high school male volleyball players. *J Sport Leis Stud*, 46, 1181–1189.

Hewett, T.E., Lindenfeld, T.N., Riccobene, J.V., & Noyes, F.R. (1999). The effect of neuromuscular training on the incidence of knee injury in female athletes. *American Journal of Sports Medicine*, 27, 699–706.

Hibbs, A.E., Thompson, K.G., French, D., Wrigley, A., & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports medicine*, 38(12), 995-1008.

Jones, P.A., & Bampouras, T.M. (2010). A comparison of isokinetic and functional methods of assessing bilateral strength imbalance. *Journal of Strength & Conditioning Research*, 24, 1553–1558.

Jovanovic, M., Sporis, G., Omrcen, D., & Fiorentini, F. (2011). Effects of speed, agility, quickness training method on power performance in elite soccer players. *The Journal of Strength & Conditioning Research*, 25(5), 1285-1292.

Junge, A., Rösch, D., Peterson, L., Graf-Baumann, T., & Dvorak, J. (2002). Prevention of soccer injuries: A prospective intervention study in youth amateur players. *American Journal of Sports Medicine*, 30, 652–659.

Kim, K.J., & Chung, J.W. (2009). Effect of 10-week core rehabilitation training on flexibility, isokinetic muscle strength, driver shot performance, and pain in elite golfers with low back pain. *Exerc Sci*, 18, 115–124.

Lee, M,, & Han, G. (2016). The effect of peculiar complex core balance training on isokinetic muscle functions of the knee and lumbus. *Journal of physical therapy science*, 28(4), 1294-1297.

Little, T., & Alun, G.W. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. *The Journal of Strength & Conditioning Research*, 19 (1), 76-78.

Mjolsnes, R., Arnason, A., Osthagen, T., Raastad, T., & Bahr, R. (2004). A 10- week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scandinavian Journal of Medicine & Science in Sports*, 14,311–317.

Nesser, T.W., Huxel, K.C., Tincher, J.L., & Okada, T. (2005). The relationship between core stability and performance in division I football players. *The Journal of Strength & Conditioning Research*, 22(6), 1750-1754.

Okada, T., Huxel, K.C., & Nesser, T.W. (2011). Relationship between core stability, functional movement, and performance. *The Journal of Strength & Conditioning Research*, 25(1), 252-261.

Olsen, O.E., Myklebust, G., Engebretsen, L., Holme, I., & Bahr, R. (2005). Exercises to prevent lower limb injuries in youth sports: Cluster randomised controlled trial. *British Medical Journal*, 330, 449.

Ozmen, T., & Aydogmus, M. (2016). Effect of core strength training on dynamic balance and agility in adolescent badminton players. *Journal of bodywork and movement therapies*, 20(3), 565-570.

Scibek, J.S. (1999). The effect of core stabilization training on functional performance in swimming (*Doctoral dissertation, University of North Carolina at Chapel Hill*).

Sever, O., & Zorba, E. (2018). Comparison of effect of static and dynamic core exercises on speed and agility performance in soccer players. *Isokinetics and Exercise Science*, 26(1), 29-36.

Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., Bizzini, M., & Andersen, T.E. (2009). Comprehensive warm-up programme to prevent injuries in young female footballers: Cluster randomised controlled trial. *British Medical Journal*, 337, 95-99

Song, Y.K., & Hong, S.M. (2012). The effect of core strengthening on the isokinetic muscular strength in university baseball players. *J Coach Dev*, 14, 91–105.

Stanton, R., Reaburn, P.R., & Humphries, B. (2004). The effect of short-term Swiss ball training on core stability and running economy. *The Journal of Strength & Conditioning Research*, 18(3), 522-528.

Tse, M.A., McManus, A.M., & Masters, R.S. (2005). Development and validation of a core endurance intervention program: implications for performance in college-age rowers. *The Journal of Strength & Conditioning Research*, 19(3), 547-552.

Willson, J.D., Dougherty, C.P., Ireland, M.L., & Davis, I.M. (2005). Core stability and its relationship to lower extremity function and injury. *Journal of the American Academy of Orthopaedic Surgeons*, 13(5), 316-325.

Wong, P. (2005). Soccer injury in the lower extremities. *British Journal of Sports Medicine*, 39, 473–482.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *Jama*, 310(20), 2191.

Yang, S.W. (2014). The effect of core training on isokinetic muscle power of knee joint and lumbar joint in short-distance athlete. *J Coach Dev*, 16, 81–87.

Yu, J.H., & Lee, G.C. (2012). Effect of core stability training using pilates on lower extremity muscle strength and postural stability in healthy subjects. *Isokinetics and exercise science*, 20(2), 141-146.