FACULTY OF SPORTS STUDIES
Masaryk University

PROCEEDINGS OF THE

11th INTERNATIONAL CONFERENCE ON KINANTHROPOLOGY

2017

29. 11. – 1. 12. 2017
Brno, Czech Republic

ISBN 978-80-210-8917-4

BILATERAL KINEMATIC INDICATORS OF THE SPECIFIC HIP AND KNEE POSTURAL ADAPTATION OF HANDBALL PLAYERS

Kiseljak Dalibor[1,2], Pažin Krešimir[1], Bolčević Filip[1]
[1]University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia
[2]University of Applied Health Sciences, Zagreb, Croatia

Abstract

Purpose: Considering the everyday training, handball players promote specific postural adaptation. Determining of postural and functional unilateral sports inherent asymmetry could improve the performance and provide injury prevention. The aim of this study was to examine whether there were significant differences in hip and knee range of motion (ROM), in all planes, between stance and kicking leg of handball players.

Methods: Research was conducted in the Laboratory for biomechanics of the Institute of Kinesiology at the Faculty of Kinesiology, University of Zagreb, during May 2016. Assessment was performed in 2 stages, on a randomized sample comprised of 25 male subjects, age ranging from 19 to 24 years with a mean 21.8. Participants were recruited from the population of students who train handball 10.44 ± 3 years. Based on the short version of the International Physical Activity Questionnaire (IPAQ), a high level of physical activity of the participants was determined. Kinematic measurements were performed through the Modified Thomas Test (MTT), which is standard for sagittal evaluation of the passive hip extension and knee flexion, giving the information on the flexibility of monoarticular and biarticular hip flexors, whose segmental postural adaptation can generate end movements in other planes. Therefore, the sample of variables were 4 angles: knee flexion and hip extension, rotation and abduction, all bilaterally.The research was performed using automatized optoelectronic kinematic measurement system ELITE 2002 (BTS Bioengineering Corp., Milano) with 8 cameras, frequency 100 Hz and 9 passive markers placed at bony prominences. Data processing was done using the Smart Analyzer software package. Since distribution showed normality, the t-test for independent samples was used. Calculations were performed using Statistica 12 software package.

Results: Kicking leg was more mobile in the hip, through the extension ROM (2.36°, $p=0.18$), and especially in the frontal plane where significantly higher abduction angle was found (2.55°, $p=0.03$). Knee ROM was greater for the stance leg, although no significance was found (1.56°, $p=0.45$). Posture in the horizontal plane was neutral for both legs.

Conclusions: Handball players are characterized by greater mobility of the kicking leg in the hip. With the exception of hip abduction, this study has not found

that multi-year handball training forms a postural adaptation of the lower extremities with significant bilateral asymmetries. Bilateral kinematic indicators determined in this study could contribute to a better understanding of the role of segmental hip and knee movements in posture, postural adaptation and locomotion of handball players, and provide guidelines for the prevention and rehabilitation of neuromuscular deficits and their consequences.

Key words: *unilaterality, stance leg, kicking leg, ROM, Modified Thomas Test, optoelectronic kinematic measurement*

Introduction

Handball is a highly strenuous contact team sport with a strong emphasis on running speed, jumping, abrupt changes in direction, and throwing (Gorostiaga et al., 1999, as cited in Setuain et al., 2015). Team handball is an attractive dynamic sport game that is very popular in Europe as well as countries in Africa, South America and Asia. In most of these countries, team handball is practiced and played often professionally (Wagner et al., 2017). Handball performance is, to some extent, affected by the anthropometric characteristics of athletes and it is possible that such characteristics differentiate players of a different competitive level (Milanese et al., 2011, as cited in Ghobadi et al., 2013). Due to the everyday training, handball players develop specific postural adaptation encompassing joint, muscular and connective tissue structures of the locomotor system as well as the central nervous system. Handball is characterized by changes in the role of musculature, from stabilization to mobilization, with different types of contractions. The athletic performance in handball depends on the athletes' health and quality of movement, that is, among others, based on posture and postural control.

Postural and functional asymmetry detection could help in prevention of the potential imbalance patterns that may promote among handball players. In advance to the higher injury risk associated with muscular imbalances, athletic performance could also be impaired through the absence from the training and/or the modification of technique due to health reasons. Muscular imbalance is a term frequently used in the area of sport performance, injury prevention and rehabilitation, describing substantial deviation from normative data or muscle performance differences between limbs. Such imbalances are associated with poor performance and higher injury risk. Previous injury, or specific sport demands, have been suggested as possible reasons that could result in the development of bilateral muscle strength imbalances among athletes (Rahnama, Lees & Bambaecichi, 2005). Previous studies have shown bilateral strength imbalances to be present in well-trained athletes (Jones & Bampouras, 2010;

Rahnama et al., 2005). It is known that athletes with insufficient postural mechanisms have an increased injury risk (Han et al., 2016; Nagai et al., 2013; Switlick, Kernozek & Meardon 2015). In handball these aspects are more pronounced because of the sports technique, which dominantly requires unilateral performance. The problem arises in insufficient focus on preventive and corrective exercises during training. Evidence of postural and functional asymmetries can be a helpful tool for a safe and efficient movement, with injury prevention and thus improved athletic performance.

Foot velocity is influenced by a sequential summation of forces from muscles acting around the pelvis, hip, knee and ankle joints (Young et al., 2003). Both the hip and knee have been implicated as influencing the strain placed upon the anterior cruciate ligament (ACL), with frontal and sagittal joint angles and moments identified as injury risk factors (Greska et al., 2016). When assessing the hip in association with other joints, it is important to observe the knee and lumbo-pelvic complex. Lower limb bilateralism with neuromuscular differences between stance and kicking extremity, may affect patterns in the background of sports performance. Gomes, de Castro & Becker (2008) suggest that examining the hip ROM should become a routine part of the decision-making process in football players with unstable knees.

The aim of this study was to examine the hip and knee posture and postural adaptation among handball players. Therefore, the purpose of the research was to recognize bilateral indicators of postural adaptation for optimizing performance including injury prevention that plays an important role in the quality of handball training and competition. Clinical test that can provide useful information regarding postural adaptation is the Modified Thomas Test (MTT). No scientific report has been published showing the kinematic analysis of MTT among handball players. The objective of this study was to examine whether there were significant differences in hip and knee ROM, in all planes, between handball players' kicking and stance leg. It was hypothesized that a difference would be noted for leg dominance, with the stance leg displaying more stability, in relation to the more mobile kicking leg. The assumption underlying this research is that this segmental clinical test of flexibility has predictive ability in relation to dynamic activities.

Methods

Research was conducted in the Laboratory for biomechanics of the Institute of Kinesiology at the Faculty of Kinesiology, University of Zagreb, during May 2016. Assessment was performed in 2 stages, on a randomized sample comprised of 25 male subjects (1.84 ± 0.59 m, 84.8 ± 9.57 kg) age ranging from 19 to 24 years with a mean 21.8. Participants were recruited from the population of students who train handball

10.44 ± 3 years. The reported data consisted of 50 lower extremities. Kinematic measurements were performed using the MTT, standardized observational clinical test for posture and lower extremity kinematics postural adaptation assessment through sagittal evaluation of the passive gravitational hip extension and knee flexion, giving the information on the flexibility of one-joint and two-joint hip flexors, whose segmental postural adaptation could generate end movements in other planes as well. Objectification of the test usually includes 2D goniometric and trigonometric methods, and in this research the 3D kinematic analysis of MTT was applied. The research was performed using automatized optoelectronic kinematic measurement system ELITE 2002 (BTS Bioengineering Corp., Milano) with 8 cameras, frequency 100 Hz and 9 passive retroreflective markers placed at bony prominences: acromion L&R, ASIS L/R, medial femoral epicondyle L/R, lateral femoral epicondyle L/R, medial tibial epicondyle L/R, fibular head L/R, medial malleolus L/R, lateral malleolus L/R. The study was approved by the Faculty's Ethics Committee and all subjects provided written informed consent to participate. At the time of the examination, no respondent has had any injuries or surgery for three years, as evidenced by a specially constructed anamnestic questionnaire. Each participant was measured by the same examiner (the principal examiner was a master physiotherapist with 11 years of clinical experience), according to the same procedure (positioning of the participants, marker placement), at the same time of the day (am), with the most similar atmospheric conditions. Two kinesiologists, with 3 and 4 years of clinical experience, took part in the research, making the anthropometric evaluation, the computerized data recording and the adjustment of measuring tools between sequences of the examination. The subjects did not have intense physical activity minimally 12 hours prior to examination. The kicking leg is defined as the leg that the participant would use to kick a ball. The non-kicking leg was handball player's stance leg. The extremity first to be measured was randomized by a coin method. After marker placement, participants were positioned for MTT (Figure 1) and given instructions for performing the test according to the protocol, based on the relevant literature (Cheatham & Kolber, 2016; Harvey, 1998; Kendall et al., 2005; Magee, 2006). The test was repeated for the other limb.

Figure 1. Modified Thomas Test protocol

Flexibility of *m. iliopsoas* was assessed by measuring hip extension ROM, thus of *m. rectus femoris* by measuring along with knee flexion ROM. Flexibility of *m. tensor fasciae latae* was assessed by measuring hip abduction ROM in the frontal plane, with hip internal rotation ROM in the transverse plane. Kinematic data from MTT were collected using automatized optoelectronic system ELITE 2002. Measurement and data acquisition were performed using the GaitEliClinic software package, a part of the BTS ELITE 2002 system. Furthermore, data processing was performed using the SmartAnalyzer software package. The features of the BTS system enable measurement with high spatial and temporal resolution, and automatic detection and acquisition of a 3D trajectory coordinates of a number of markers. The system functions based on automatic detection of coordinates of retroreflective passive markers by the method of cross-correlation, and by employing close-range photogrammetry algorithms for calculation of 3D marker coordinates. When marker trajectories are acquired, a number of kinematic parameters of a particular recorded movement can be calculated (Medved, 2001). In total, 400 angles were computed while 6 fell out the experiment, due to sweating, 3D method artefacts and trick movements. The sample of variables were 4 angles: knee flexion, hip extension, hip rotation and hip abduction, all bilaterally.

Normality in data distribution was examined using the Kolmogorov-Smirnov test. The level of significance was set at $p = 0.05$. After the whole data showed normality, group differences were evaluated using the t-test for independent samples. Significance was accepted at the $p \leq 0.05$ level of confidence and all results are reported as mean ± SD. All data were analysed by the Statistica 12 software package.

Results

Optoelectronic kinematic evaluation results are presented in Figure 2, showing that kicking leg was more mobile in the hip, through the extension ROM (**25.84° ± 9.1°** / *23.47° ± 8.22°* \2.36°, p=0.18), and especially in the frontal plane where significantly higher abduction angle was found (**9.03° ± 6.9°** / *6.48° ± 4.8°* \2.55°, p=0.03). Knee ROM was greater for the stance leg, although no significance was found (*54.32° ± 10.91°* / **52.76° ± 9.71°** \1.56°, p=0.45). Posture in the horizontal plane was almost neutral for both legs (*0.4° ± 4.22°* / **0.06° ± 5.23°** \0.34°, p=0.72).

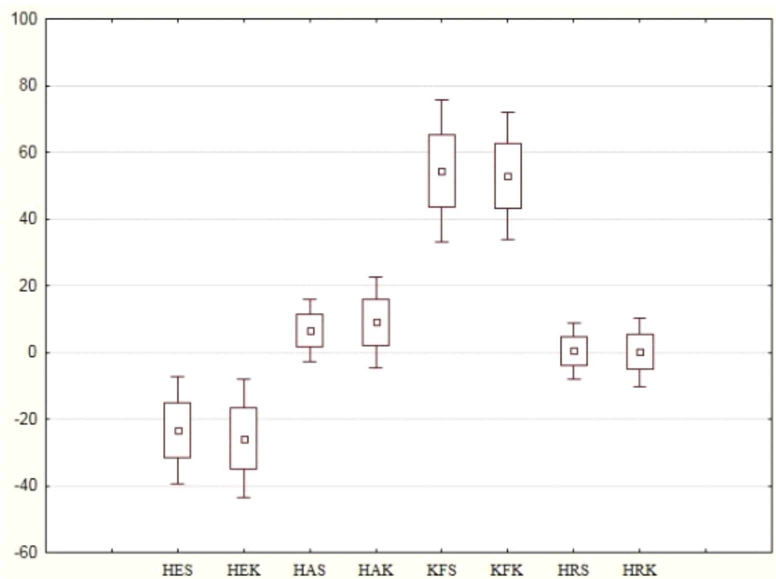

Figure 2. Results of measuring 4 ROM parameters bilaterally: **HES** – stance leg hip extension, **HEK** – kicking leg hip extension, **HAS** – stance leg hip abduction, **HAK** – kicking leg hip abduction, **KFS** – stance leg knee flexion, **KFK** – kicking leg knee flexion, **HRS** – stance leg external hip rotation, **HRK** – kicking leg external hip rotation

Discussion

The aim of the present study was to investigate the application of MTT for the assessment of lower limb bilateral imbalance among handball players. Examination of the lower extremity muscle length was performed indirectly, by testing hip and knee ROM of kicking and stance leg, compared side-to-side. No significant differences between limbs were found, with the exception of the hip abduction ROM, which was significantly greater for the kicking leg. According to Bradley & Portas (2007), previous literature has postulated that a lack of muscle flexibility is an important intrinsic risk factor for the development of muscle strain injuries in sport. In their research, aforementioned authors found no significant relationships between muscle strain injury and limb dominance intrinsic risk factor, which opposes the findings of previous studies. Our main results showed more mobility in the hip for the kicking leg, significant only in the variable hip abduction. In the knee the stance leg showed more mobility, but without significance. In handball, the basic offensive position, as well as most of the attack movement solutions, aligns the kicking leg predominantly externally rotated and abducted; e.g. during the jump shot, the kicking leg is used to achieve the additional impulse that is obtained at the take-off level. Initially, kicking leg is flexed in the hip and knee joint, followed by extension in the two joints to achieve additional impulse when throwing the ball. Throughout the whole cycle the kicking-side thigh is abducted and the iliotibial region is constantly loaded, promoting specific postural adaptation. That could be the explanation of the increased hip abduction ROM for the kicking leg, found in the present study.

Hip extension is considered to be important in performing various sport activities. A lack of hip extension has been theorized to lead to an over striding gait and increased impact forces during running (Derrick, Hamill & Caldwell, 1998). Husson et al. (2010) point out the lumbo-pelvic-hip complex as a paradigmatic entity in the human posture analysis, with structural and functional connections to the spine and lower extremities, while Page et al. (2010) elaborate various compensatory mechanisms in postural adjustment, considering the lower crossed syndrome as a guide in assessment and intervention. Lazennec, Brusson & Rousseau (2013) investigated the role of lumbosacral and pelvic regions in the continuity of functional spinal parameters, emphasizing posture and postural adaptation of the hip as a key aspect, but underestimated beside the conventional assessment approaches. There are studies (Buckeridge et al., 2012; Holt et al., 2003) that emphasize the importance of the full range of hip movements for the spinal load reduction. For individuals with low back pain, tight hip flexors may lead to compensatory spinal movements that increase spinal extension, as the individual lacks movement options due to their hip extension limitations (Vigotsky et al., 2016). A lack of hip extension may be associated with tightness in the hip flexor muscles. Postural perspective related to hamstring strains is that tight hip flexors lead to an anterior pelvic tilt, which may predispose sprint athletes to hamstring strains (Gabbe, Bennell & Finch, 2006). On their research results, Bradley & Portas (2007) suggest that preseason muscle flexibility assessment, particularly for the hip and knee flexors, is essential in elite football players to identify players with reduced ROM. Therefore, it is recommended that for athletes identified as having an "at-risk" ROM should be prescribed an appropriate flexibility training program.

Imaging studies that have assessed the role of cortical activity in simple joint movements of the hip, knee and ankle, reported that the stance leg produces a more bilateral cortical activation pattern, whereas the kicking leg produces a predominantly contralateral cortical activation pattern (Kapreli et al., 2006, as cited in Greska et al., 2016). Brown, Palmieri-Smith & McLean (2009) performed the jump-to-cut task using college-aged recreational athletes, and found that stance leg displayed greater joint excursions for hip and knee joint angles compared to the kicking leg. Brophy et al. (2010) suggested that the limb dominance might be factor in the etiology of ACL injuries, since females were more likely to injure their stance leg. Evidence for neuromuscular or biomechanical risk factors for ACL injuries in male athletes appears to be mainly related to dysfunctions occurring at the trunk and hip joint levels (Alentorn-Geli et al., 2014, as cited in Setuain et al., 2015). According to Young et al. (2003), reduced extensibility of tissues around the hip and knee joints are thought to be related to injury risk. The relationship between the static measure of flexibility and the hip and knee positions achieved during kicking was stronger than in previous research that investigated gait. The studies using gait involved submaximal speeds, which might have not required a high level of hip flexibility.

Potential disadvantage of the present study relies on the complex comparison between segmental assessment, gait analysis and handball specific motion in training and competition, from the postural and functional aspects. Nevertheless, segmental tests could give guidelines for corrective sport performance exercises in the context of holistic prevention. The findings of Jones & Bampouras (2010) provide support for the use of field tests to detect imbalances between lower limbs.

Conclusion

Handball players are characterized by greater mobility of the kicking leg in the hip. With the exception of hip abduction, this study has not found that multi-year handball training forms a postural adaptation of the lower extremities with significant bilateral asymmetries. Bilateral kinematic indicators determined in this study could contribute to a better understanding of the role of segmental hip and knee movements in posture, postural adaptation and locomotion of handball players, and provide guidelines for the prevention and rehabilitation of neuromuscular deficits and their consequences. The results support the use of segmental clinical tests in lower limb asymmetry detection, allowing kinesiologists and/or physiotherapists to determine whether an athlete is in need of a training program that emphasizes additional exercises for improvement of the bilateral postural balance. The knowledge gained from this research could be especially useful in training and injury prevention approach with young athletes.

References

Bradley, P. S., & Portas, M. D. (2007). The relationship between preseason range of motion and muscle strain injury in elite soccer players. *J Strength Cond Res*, *21*(4), 1155-1159.

Brophy, R., Silvers, H. J., Gonzales, T., & Mandelbaum, B. R. (2010). Gender influences: the role of leg dominance in ACL injury among soccer players. *Brit J Sport Med*, 44(10), 694-697.

Brown, T. N., Palmieri-Smith, R. M., & McLean, S. G. (2009). Sex and limb differences in hip and knee kinematics and kinetics during anticipated and unanticipated jump landings: implications for anterior cruciate ligament injury. *Brit J Sport Med*, *43*(13), 1049-1056.

Buckeridge, E., Hislop, S., Bull, A., & McGregor, A. (2012). Kinematic asymmetries of the lower limbs during ergometer rowing. *Med Sci Sport Exer*, *44*(11), 2147-2153.

Cheatham, S. W., & Kolber, M. J. (2016). *Orthopedic Management of the Hip and Pelvis*. St. Louis, MO: Elsevier Health Sciences.

Derrick, T. R., Hamill, J., & Caldwell, G. E. (1998). Energy absorption of impacts during running at various stride lengths. *Med Sci Sport Exer*, *30*(1), 128-135.

Gabbe, B. J., Bennell, K. L., Finch, C. F., Wajswelner, H., & Orchard, J. W. (2006). Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Spor*, *16*(1), 7-13.

Ghobadi, H., Rajabi, H., Farzad, B., Bayati, M., & Jeffreys, I. (2013). Anthropometry of world-class elite handball players according to the playing position: reports from men's handball World championship 2013. *J Hum Kinet*, *39*(1), 213-220.

Gomes, J. L. E., de Castro, J. V., & Becker, R. (2008). Decreased hip range of motion and noncontact injuries of the anterior cruciate ligament. *Arthroscopy*, *24*(9), 1034-1037.

Greska, E. K., Cortes, N., Ringleb, S. I., Onate, J. A., & Van Lunen, B. L. (2016). Biomechanical differences related to leg dominance were not found during a cutting task. *Scand J Med Sci Spor*

Han, J., Waddington, G., Adams, R., Anson, J., & Liu, Y. (2016). Assessing proprioception: a critical review of methods. *J Sport Health Sci*, *5*(1), 80-90.

Harvey, D. (1998). Assessment of the flexibility of elite athletes using the modified Thomas test. *Brit J Sport Med*, *32*(1), 68-70.

Holt, P. J. E., Bull, A. M. J., Cashman, P. M. M., & McGregor, A. H. (2003). Kinematics of spinal motion during prolonged rowing. *Int J Sports Med*, *24*(08), 597-602.

Husson, J. L., Mallet, J. F., Parent, H., Cavagna, R., Vital, J. M., Blamoutier, A., & Violas, P. (2010). The lumbar-pelvic-femoral complex: applications in spinal imbalance. *Orthop Traumatol-sur*, *96*(4), S1-S9.

Jones, P. A., & Bampouras, T. M. (2010). A comparison of isokinetic and functional methods of assessing bilateral strength imbalance. *J Strength Cond Res*, *24*(6), 1553-1558.

Kendall, F. P., McCreary, E. K., Provance, P. G., Rodgers, M. M., & Romani, W. A. (2005). *Muscles Testing and Function with Posture and Pain*. 5th ed. Baltimore, MD: Lippincott Williams & Wilkins.

Lazennec, J. Y., Brusson, A., & Rousseau, M. A. (2013). Lumbar-pelvic-femoral balance on sitting and standing lateral radiographs. *Orthop Traumatol-sur*, *99*(1), S87-S103.

Magee, D. J. (2006). *Orthopedic Physical Assessment*. 4th ed. Philadelphia, PA: WB Saunders Co.

Medved, V. (2001). *Measurement of human locomotion*. Boca Raton, Fla: CRC press.

Nagai, T., Sell, T. C., House, A. J., Abt, J. P., & Lephart, S. M. (2013). Knee proprioception and strength and landing kinematics during a single-leg stop-jump task. *J Athl Training*, *48*(1), 31-38.

Page, P., Frank, C., & Lardner, R. (2010). *Assessment and treatment of muscle imbalance: the Janda approach*. Champaign, IL: Human kinetics.

Rahnama, N., Lees, A., & Bambaecichi, E. (2005). A comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. *Ergonomics*, *48*(11-14), 1568-1575.

Setuain, I., González-Izal, M., Alfaro, J., Gorostiaga, E., & Izquierdo, M. (2015). Acceleration and orientation jumping performance differences among elite professional male handball players with or without previous ACL reconstruction: An inertial sensor unit-based study. *PM&R*, *7*(12), 1243-1253.

Switlick, T., Kernozek, T. W., & Meardon, S. (2015). Differences in joint-position sense and vibratory threshold in runners with and without a history of overuse injury. *J Sport Rehabil*, *24*(1), 6-12.

Vigotsky, A. D., Lehman, G. J., Beardsley, C., Contreras, B., Chung, B., & Feser, E. H. (2016). The modified Thomas test is not a valid measure of hip extension unless pelvic tilt is controlled. *PeerJ*, *4*, e2325.

Wagner, H., Fuchs, P. X., & von Duvillard, S. P. (2017). Specific physiological and biomechanical performance in elite, sub-elite and in non-elite male team handball players. *J Sport Med Phys Fit*

Young, W., Clothier, P., Otago, L., Bruce, L., & Liddell, D. (2003). Relationship between a modified Thomas test and leg range of motion in Australian-Rules football kicking. *J Sport Rehabil*, *12*(4), 343-350.