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## RESEARCH ARTICLE

# ISOKINETIC STRENGTH PROFILE OF HIP MUSCLE GROUPS AT TWO DIFFERENT TESTING POSITIONS.

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### Abstract

The purpose of this research was to compare isokinetic strength of hip muscles at two different testing positions in healthy male and female subjects. Twenty-two male and seventeen female subjects were included in this study. Isokinetic concentric ratios of the hip muscle groups were recorded in supine and standing (for flexors/extensors) and side-lying and standing positions (for adductors/abductors) at different angular velocities (60°, 180°/s). The isokinetic ratios of hip muscle groups significantly increased with increasing test velocity in both the supine/side-lying and standing position for all subjects. Also, the hip muscle groups' ratios increased in the standing position at 60°/s for all subjects and at 180°/s for male subjects only, which indicated that males experienced greater increases in hip muscles strength ratios in standing position at 180°, whereas females demonstrated less ratios in the same position. It was concluded that, with a high angular velocity in standing position, the isokinetic tests of hip muscles' groups ratios provide a strong indicator for hip muscles imbalance. Consequently, muscular deficiencies occurring at specific contractile speeds might be identified and corrected by having the patient exercise isokinetically at the speeds at which the deficiencies occurred.

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## INTRODUCTION

Torque generated by muscle is influenced by many factors such as angular velocity, stabilization, subject positioning, and the conditions under which the muscle torque was measured (Gaines and Talbot, 1999; Barbic and Brouwer, 2008). Isokinetic testing methodology of musculoskeletal system is not only vast but seems to be quite away from standardization. In particular, reference is made to the hip, trunk, and shoulder musculature. Testing of trunk muscles is still being done in either the sitting or upright position resulting in significantly different test findings. However, sitting is more comfortable for testing back pain patients, standing is more convenient for job screening testing of normal subjects. The same applies to hip muscles which need proper stabilization that offered while the subject lying supine or side-lying depending on the muscle group of interest, however improper stabilization will affect the results (Dvir, 2000). Furthermore, the side-lying body position provides the most valid and reliable assessment of unilateral hip abductor strength in clinical settings, and it is also recommended by most manufacturers of isokinetic testing devices (Hislop and Montgomery 2002; Widler et al., 2009) and was used for testing a variety of population, such as baseball pitchers (Tippet, 1986), healthy children (Burnett et al., 1990), normal adults (Donatelli et al., 1991), and hockey players (Kea et al., 2001). On the other hand, testing of hip muscles may be performed from standing position because it is more physiologically relevant and most of our functional activities are performed while the body in upright position likes walking, running, stair climbing and

playing football (Dvir, 1995), and have been used for testing soccer players (Poulmedis, 1985), amputees (Ryser et al., 1988), and impaired subjects (Cahalan et al., 1989).

However, standing position imitate how the muscles are used during functional activities, this allow free movement of tested limb with simultaneous load bearing on the other limb which may produce balance disturbance (Dvir, 1995; Porter and Vandervoort, 1997; Dvir, 2000, Julia et al., 2010). For estimating the balance or imbalance of muscle forces around a joint, we must determine the ratios of torques of agonist/antagonist muscles. This ratio is important for preventing muscular injuries. In imbalance, the weaker group of muscles may be subjected to the action of dangerous mechanical stresses (Pontaga, 2003). Little is known about the influence of test position and angular velocity on agonist/antagonist ratios yet the information could be clinically relevant, and many isokinetic test positions used supine or side-lying positions, even though they are antigravity positions for tested muscles, but they are not functional positions. This study explored whether positioning subjects in supine/side-lying or standing with different angular velocities influenced agonist/antagonist ratios of the hip muscles in both male and female subjects. We hypothesized that, males will create higher peak torque values than females, and the peak torque value will be higher when tested at 60°/s than when tested at 180°/s.

## **MATERIAL AND METHODS**

### **Participants**

A sample of seventeen female and twenty-two male subjects were participated in the study. All subjects conducted this study in a random order. Table (1) shows the demographic data for both groups. The exclusion criteria were previous history of surgery, trauma in the back and lower extremity. All participants in this study were right-leg dominant. Prior to actual measurements, participants received an explanation of the study procedures and they provided written informed consent. The research and the written informed consent were approved by the ethics committee of the Faculty of Physical Therapy, Cairo University.

### **Instrumentation**

A Biodex 3 Multi-joint Testing and Rehabilitation System (Biodex Medical System, Shirley, NY, USA) was used. Torque values were gravity-adjusted. Calibration of the Biodex dynamometer was automatically performed at the beginning of each session.

### **Procedures**

Participants executed a 10 min warm-up bout prior to entering the laboratory and collecting hip strength measures. The warm up procedure consisted of stretching exercise for the hip flexors, extensors, abductors, and adductors muscles, which was found to be effective in increasing the concentric isokinetic torque (Abdel-aziem and Mohammad, 2012). Stretching exercise done for 10 min (10 sec hold stretch/10 sec relax). The muscle groups tested (hip muscles) for all subjects and the testing position were conducted in a randomized order to prevent dependent ordering effect. The dominant limb was tested. Leg dominance was demonstrated by the preferred kicking leg. Rest periods of 5 min were given between the tests of each muscle group. Throughout all testing, participants were verbally encouraged to perform maximal contractions through the range of motion (ROM). Participants performed isokinetic concentric contraction of hip muscles at angular velocity of 60°/s and 180°/s as previously recommended in the literature (Masuda et al., 2003; Masuda et al., 2005).

The velocity range (a slow [60°/s] and a rapid [180°/s]) concentric-mode test was selected for their high reproducibility regardless of the body side, test velocity and contraction mode. Low velocity, concentric tests probe the muscles' performances in terms of maximum strength, whereas the high velocity concentric tests tend to give more information on "explosive" strength, and mimic the speed quantified during high-risk cutting tasks. Moreover, the high velocity test was limited to 180°/s because preliminary experiments revealed that the subjects had great difficulty performing the movement at higher velocities (notably at 240°/s), the truly isokinetic range of joint movement was very narrow or even inexistent, which reduced the measurements' reliability (Julia et al., 2010). In each hip muscle test, the effect of gravity was compensated by gravity automatic correction.

For testing hip flexors and extensors in supine position, the chair back was set horizontally in line with the seat pan and subject lay on his/her back. Straps stabilized the trunk, pelvis and the non-test limb (Barbic and Brouwer, 2008). When testing in standing, the hip attachment was inserted into the knee adaptor and secured to the dynamometer. The subject was positioned in the standing position lateral to the dynamometer system, the limb in neutral position, with the axis of the dynamometer aligned superior and anterior to the greater trochanter (Mohammad et al., 2014).

For testing hip adductors and abductors in side-lying position, the chair back was set horizontally in line with the seat pan and subject lay on his/her side with the tested leg above. Straps stabilized the trunk, pelvis, and the non-

test limb (Lee and Powers, 2013). When testing hip abduction and adduction in standing position, the subject was positioned in the standing position facing away from the dynamometer with the axis of the dynamometer aligned with the anterior superior iliac spine (Mohammad et al., 2014).

The actual test contained two sets, each one consisted of five repetitions (according to Brown and Whitehurst, 2000), with a rest period of 60 seconds between the sets. The highest value of the five repetitions in one set was recorded and the mean value of the two sets was used for statistical analysis. The outcome parameter was the peak torque (expressed in Nm) which was normalized to the participants' body weight (expressed in Nm/kg) in an effort to reduce inter-subject variability in raw scores of quantitative muscle tests. All test trials were conducted by a single tester to limit potential inter-rater test error.

### Statistical analysis

Data was analyzed using a Statistical Package for Social Sciences (version 20.0 for Windows; SPSS Inc, Chicago, IL). A multivariate analysis of variance (MANOVA) was conducted for hip flexor/extensor and adductor/abductor muscles ratios during different testing position at angular velocities of 60°/s and 180°/s for both groups. In case the *F* ratio was significant, the differences between ratios were examined using the Tukey test. The level of significant was set at  $p < 0.05$  for all statistical tests.

## RESULTS

Peak torque values obtained from the standing and supine/side-lying positions at 60°/s and 180°/s for the hip flexor, extensor, adductor, and abductor muscle groups for all subjects are presented in Table (2). There was a significant decrease in hip muscles ( $p < 0.05$ ) peak torque values with increasing test velocity. For all subjects, hip muscles peak torque values were greater ( $p < 0.05$ ) in the standing position than in the supine or side-lying position at all test speeds. Males generated greater peak torque than females ( $p < 0.05$ ) for hip muscle groups.

Table (3) presents the hip muscle groups ratios obtained from both test positions. The flexion/extension and adduction/abduction muscle groups ratios increased with increasing test velocity in both the supine/side-lying and standing position for all subjects ( $p < 0.05$ ). Also, the hip muscle groups' ratios increased from the supine/side-lying position to the standing position at 60°/s for all subjects and at 180°/s for male subjects.

A significant interaction was found for hip flexor/extensor ( $p < 0.05$ ) and adductor/abductor muscles ratios ( $p < 0.05$ ) between the two tested positions and the two angular velocities in both groups. Tukey test showed that, there was a significant decrease in flexor/extensor ( $p < 0.05$ ) and adductor/abductor ( $p < 0.05$ ) ratios at 180°/s in standing position in female subjects.

**Table 1.** Demographic data for male and female subjects

Groups	Male <i>n</i> =22	Female <i>n</i> =17
Age (years)	21.83 ± 3.35	21.25 ± 3.51
Height (cm)	175.17 ± 2.85	155.75 ± 2.38
Weight (kg)	71.04 ± 3.72	53.89 ± 4.43
Body mass index	23.35 ± 1.21	22.13 ± 1.79

**Table 2.** The mean values of peak torque/body ( $\pm$ SD) for the hip muscles during concentric modes of contraction at angular velocities 60°/s and 180°/s.

Variables	Position	Male		Female	
		60°/s	180°/s	60°/s	180°/s
Hip flexors	Supine	1.34 $\pm$ 0.11	1.14 $\pm$ 0.11	1.12 $\pm$ 0.08	1.02 $\pm$ 0.15
	Standing	1.77 $\pm$ 0.10	1.85 $\pm$ 0.16	1.19 $\pm$ 0.10	1.07 $\pm$ 0.13
Hip extensors	Supine	1.52 $\pm$ 0.13	1.29 $\pm$ 0.12	1.45 $\pm$ 0.07	1.07 $\pm$ 0.32
	Standing	1.87 $\pm$ 0.12	1.72 $\pm$ 0.05	1.50 $\pm$ 0.18	1.30 $\pm$ 0.05
Hip adductors	Side-lying	1.14 $\pm$ 0.04	1.05 $\pm$ 0.16	0.87 $\pm$ 0.15	0.77 $\pm$ 0.12
	Standing	1.94 $\pm$ 0.14	1.70 $\pm$ 0.02	1.35 $\pm$ 0.12	1.11 $\pm$ 0.08
Hip abductors	Side-lying	0.96 $\pm$ 0.14	0.90 $\pm$ 0.16	0.81 $\pm$ 0.03	0.71 $\pm$ 0.12
	Standing	1.61 $\pm$ 0.11	1.43 $\pm$ 0.12	1.28 $\pm$ 0.06	1.07 $\pm$ 0.02

SD: standard deviation.

**Table 3.** The hip flexors/extensors and adductor/abductor ratios at angular velocities 60°/s and 180°/s.

Ratios	Position	Male		Female	
		60°/s	180°/s	60°/s	180°/s
Hip flexors/extensors	Supine	0.88 $\pm$ 0.11	0.97 $\pm$ 0.12	0.77 $\pm$ 0.11	0.91 $\pm$ 0.21
	Standing	0.94 $\pm$ 0.13	0.98 $\pm$ 0.09	0.79 $\pm$ 0.13	0.82 $\pm$ 0.12
Hip adductors/abductors	Side-lying	1.17 $\pm$ 0.22	1.18 $\pm$ 0.19	1.01 $\pm$ 0.19	1.16 $\pm$ 0.37
	Standing	1.20 $\pm$ 0.09	1.22 $\pm$ 0.11	1.06 $\pm$ 0.13	1.08 $\pm$ 0.06

## DISCUSSION

This study was conducted to compare the isokinetic torques of flexors/extensors and adductors/abductors muscles in two different testing positions and two different angular velocities. The results of this study proved that testing position affect hip muscles ratios in high speed with consideration of gender tested. The findings of this study support the first hypothesis and demonstrate that the peak torque values of males tended to be greater than that of females. On the same context several studies have shown that males test significantly stronger than females (Cahalan et al., 1989; Kushner et al., 1992; Brent et al., 2013).

In this study, the mean PT/BW values of the hip flexor, extensor, adductor, and abductor muscles were significantly higher in standing position than in supine or side-lying at angular velocities of 60°/s and 180°/s. This finding was similar to that showed by Barbic and Brouwer (2008), who found that hip flexor and extensor torques measured in standing were higher than in supine at 60°/s. A possible explanation for higher muscle activity in the upright position may be the activation of contralateral (non-tested) hip abductors to prevent the pelvic drop on the tested limb. This results in extremely high levels of activation of both gluteus medius muscles in standing position to provide pelvis stabilization against gravity (Widler et al., 2009). In this context, hip muscle strength has a better correlation with the velocity of movement in the standing position than in the lying position (Farrar and Thorland, 1987), and recruited of a number of postural muscles in to enhance their stability (Kawaguchi and Babcock, 2010).

This finding is in contrast to Bolgla and Uhl (2005), and Widler et al. (2009). Widler et al. (2009) found that the maximal hip abductor isometric strength was significantly higher in the side-lying position compared with the standing and supine positions. One likely reason for this discrepancy in the literature may be the gravity correction was not documented in the several studies, or using different testing mode for measurement of hip abductors and adductors strength such as the isometric contraction, which may not be as closely related to injury as dynamic

strength measures, typically performed isokinetically at faster, more functional speeds (Brent et al., 2013). Bolgla and Uhl (2005) demonstrated that non-weight bearing side-lying hip abduction exercise resulted in greater muscle activation than exercise in non-weight bearing standing position. This may be contributed to different exercise mode used in the previous study (resisted exercise with ankle cuff weight). The muscle strength can be assessed and quantified under more natural movement conditions through isokinetic mode rather than the isometric method (Julia et al., 2010). So, the muscle activity produced during the isokinetic testing differs in behavior from that produced during isometric or resisted exercise, even for the same muscle group and for the same testing position.

The second hypothesis, that the peak torque value would be higher when tested at 60°/s than when tested at 180°/s was also supported. This decline in torque output has been attributed to different neurological activation patterns of motor units at different velocities (Baltzopoulos and Brodie, 1989). The decrease in peak torque with the increase of angular velocity is supported by the findings of Cahalan et al. (1989), Kellis and Baltzopoulos (1995), Emery et al. (1999). Regardless age and gender, Cahalan et al. (1989) examined the hip extensors, flexors, adductors, abductors, and rotators, and reported that as the velocity of exercise increased, the magnitude of the torques produced decreased. Kellis and Baltzopoulos (1995) reported that from 60°/s, increase in the angular velocity produces a decline in torque of the concentric contractions. Emery et al. (1999) found that the hip strength peak torque decreased as the testing velocity increased in healthy male subjects. This may be explained by the relationship between force versus velocity, which assumed that as the velocity of shortening is low, the tension that can be developed is high and, on the other hand, if the velocity of shortening is high, the tension that can be developed is low (Duncan et al., 1989). Another explanation could be the existence of "qualitative recruitment," which is recruitment based upon specific demand, whereby the motor units with different functional characteristics could be selectively recruited depending upon the exact nature of the intended contraction and contractile velocity. One type of unit becomes active during slow, sustained contractions, and an entirely different unit becomes active during rapid contractions (Barnes, 1980).

The present study is, to our knowledge, the first study investigating the hip flexor/extensor and adductor/abductor strength ratio at different testing positions, and angular velocities. As described by Bolgla and Uhl (2005), the hip abductor muscles internal force either examined in non-weight bearing (side-lying or standing hip abduction) or weight bearing (standing) position, it dependent on applied external torque. While comparing interaction effect of angular velocity and testing position on hip muscles ratio in both gender, we found that for male and female subjects at angular velocity 60°/s the flexor/extensor and adductor/abductor muscles ratios were higher in standing position. At angular velocity 180°/s, these ratios become higher in standing position in male subject, however, female subjects demonstrated lower values in the same position which is a new finding and has not previously been reported in the literature, although other measures of lower extremity strength in females have shown evidence of lack of neuromuscular spurt with maturation (Hewett et al., 2004), causing neuromuscular imbalance.

Reliable assessments for hip muscles strength make it possible to objectively determine whether changes in hip strength have occurred over time, and provide a screening tool for the detection of hip muscle weaknesses in healthy individuals, which has been shown to be a risk factor for sustaining a groin injury (Tyler et al., 2001; O'Connor, 2004). For estimating the balance or imbalance of muscle forces in the joint, we must determine the ratios of torques of agonist/antagonist muscles. This ratio is important for preventing athletic traumas (Pontaga, 2003). More precisely, hip adductor/abductor muscles ratio may be an important factor for the determination of injury predisposition because hip abductor strength may be responsible for counterbalancing against the hip adduction strength in dynamic movements (Sugimoto et al., 2014). In current study, for females the values of the hip muscles ratios in supine or side-lying position were higher than standing at 180°/s only. Although higher contraction speeds resulted in lower torque values, the changing in torque values for both agonist and antagonist muscles was not occurred in the same ratio. The lower hip muscles agonist/antagonist ratios in standing position suggest that increase the demands on hip abductor and extensor in relation to adductor and flexor muscles activities specifically with increasing speed. Consequently, muscle imbalance can be detected and elucidated from standing position with high angular velocity in female subject.

Hsu et al. (2002) reported that the normalized strength measures tested under faster angular velocity tended to be more reliable than those tested under slower angular velocity. Therefore, using a high angular velocity in standing position may be a good predictor for the presence of hip muscles imbalance and hence testing of agonist/antagonist hip muscle from standing can be used as tool to predict and investigate imbalance-induced injury or trauma and consequently preventing it. The finding of this study may be helpful when developing a comprehensive rehabilitation program for patients with hip muscles imbalance, so supine or side-lying positions may be used as an initiating position for hip muscles rehabilitation then progress to standing position. In addition, muscular

deficiencies occurring at specific contractile speeds might be identified and corrected by having the patient exercise isokinetically at the speeds at which the deficiencies occurred.

This investigation examined the influence of test position and angular velocity on agonist/antagonist ratios of the hip muscles torques in a population of healthy subjects. The differences observed between the two test positions and angular velocities in this population suggest a need to explore the influence of test position and angular velocity in an athletic population.

## CONCLUSION

This study supported that the antagonist/agonist co-activation phenomenon in a functional situation varies according to many factors such as the angular velocity and the gender. Muscle imbalance is more elucidated in standing position with high angular velocity specifically in female subjects. Although higher contraction speeds resulted in lower torque values, the decreasing in torque in agonist and antagonist muscles was not occurred in the same ratio. This results in more recruitment of hip abductor and extensors muscles in relation to hip adductor and flexors muscles, respectively, in standing position. The isokinetic loading device allows direct control over contraction velocity. If it were shown that contractions performed at different speeds resulted from the recruitment of certain motor units specifically designed for those speeds, this device would seem to have great potential for specific muscular rehabilitation.

## Conflict of Interest

There is no conflict of interest.

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