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## RELATIONSHIPS BETWEEN HIP MUSCLE LENGTH, HIP JOINT ANGLE, AND PELVIC TILT IN STATIC STANDING POSTURE AMONG COLLEGE-AGED HEALTHY CAUCASIAN AND EASTERN ASIAN MALES

presented by

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has been accepted towards fulfillment of the requirements for the

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### RELATIONSHIPS BETWEEN HIP MUSCLE LENGTH, HIP JOINT ANGLE, AND PELVIC TILT IN STATIC STANDING POSTURE AMONG COLLEGE-AGED HEALTHY CAUCASIAN AND EASTERN ASIAN MALES

By

Toru Tanaka

#### **A THESIS**

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#### **ABSTRACT**

RELATIONSHIPS BETWEEN HIP MUSCLE LENGTH, HIP JOINT ANGLE, AND PELVIC TILT IN STATIC STANDING POSTURE AMONG COLLEGE-AGED HEALTHY CAUCASIAN AND EASTERN ASIAN MALES

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Relationship between pelvic tilt in standing posture and hip muscle length has been widely accepted, although it has not been sufficiently supported. First purpose of the study was to examine relationships between pelvic tilt, hip joint angle, and center of pressure in standing posture, and hip muscle length (one- and two-joint hip flexor and hip extensor) among college-aged males. Second purpose was to analyze differences in pelvic tilt and hip joint angle in standing posture and hip muscle length (one-joint hip flexor and hip extensor) between Caucasian and Eastern Asian college-aged males.

Twenty one Caucasian (M = 28.78 years, SD=1.94) and 18 Eastern Asian (M = 25.36 years, SD=3.95) male participants were recruited. No relationships were found between variables except for relationship between pelvic tilt and hip joint angle (r = .896, P < .01).

There were no race differences in pelvic tilt, hip joint angle, and hip muscle length.

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#### **CHAPTER 1**

#### INTRODUCTION AND REVIEW OF LITERATURE

Postural Imbalances and Low Back Pain in Western and Asian Populations

Throughout a lifetime, 70-80% of the people in the western population have at least one episode of low back pain (Nourbakhsh & Arab, 2002). There can be many reasons for low back pain such as genetic, social, or biomechanical. From a biomechanical point of view, many researchers have attempted to find relationships between chronic low back pain and postural imbalances such as lumbar lordosis, kyphosis, scoliosis, sway back, and flat back (Mulhearn & George, 1999; Norris 1995; Nourbakhsh & Arab, 2002; Watson, 1995). These studies used western populations, with the exception of Nourbakhsh and Arab (2002) who used a population from Iran. Postural imbalances may be the result of genetics, muscular imbalance, the assumption of poor posture of daily life, or all of them (Lee, Lee, Kim, Hong, & Yoo, 2001; Mulhearn & George, 1999; Youdas, Garrett, Egan, & Therneau, 2000). In contrast, Asian people are more prone to exhibit a flat back and sway back position than Americans and Europeans. Since there may be differences in postural imbalances between different populations, it is not clear whether or not these imbalances precipitate physical problems. According to

Kendall, McCreary, and Provance (1993), problems with flat back and sway back do not show health problems in Asian populations.

Postural Models by Kendall, KcCreary, and Provance for the Evaluation and Rehabilitation of Postural Imbalances

There may be interrelationships between pelvic tilt, hip muscle tightness, and low back pain. The orientation of the pelvis is directly related to postural imbalances and may be associated with tightness of the hip musculature. Kendall, McCreary, and Provance (1993) presented standing postural models that indicated imbalances such as lordosis, kypholordosis, flat back, and sway back (Figure 1), caused by hip muscle tightness. Approaches to the study of posture described by Kendall's text took a broader view relating whole body mechanics to interrelationships between joints, posture, and muscles. Kendall, McCreary, and Provance (1993) stated;

Evaluation of faulty posture must include examination of the related parts and not be limited to the areas where symptoms appear. A mechanical or functional strain causing an imbalance in one part of the body will soon result in compensatory changes in other parts of the body. The mechanics of the low back is inseparable from that of the overall posture but especially that of the pelvis

and the lower extremities. Pain manifested in the leg may be due to an underlying problem in the back. Conversely, the symptoms appearing in the low back may be due to underlying faulty mechanics of the feet, legs, or pelvis (pp. 349).

These models are widely accepted in clinical settings and are used extensively for evaluation and rehabilitation of postural imbalance and accompanying low back pain because they seem to explain mechanical reasons for the postural imbalances.



#### (a) Lordotic

Body segment alignment

Pelvis is anteriorly tilted with lordosis increased. Knees are hyperextended with angle joints slightly plantarflexed

Elongated and weak

Anterior abdominals.

Hamstrings may lengthen initially or shorten to compensate where posture has been present for some time

Short and strong

Low back and hip flexors



#### (b) Kypholordotic

Body segment alignment

Head held forwards with cervical spine hyperextended. Scapulae may be abducted. Increased lumbar lordosis, and increased thoracic kyphosis. Pelvis anterioriy tilted. Hip flexed, knee hyperextended. Head is usually most anteriorly placed body segment

Elongated and weak

Neck flexors, upper erector spinae. External oblique. If scapulae are abducted, middle and lower trapezius

Short and strong

Neck extensors and hip flexors.

If scapulae are abducted, serratus anterior, pectoralis major and/or minor, upper trapezius

Figure 1. Standing postural patterns from Kendall, McCreary, and Provance (1993) as modified by Norris (Norris, 1995).



#### (c) Sway Back

**Body segment alignment** 

Long kyphosis with pelvis the most anterior body segment, hip joint moves forwards of posture line. Low lumbar area flattens. Pelvis neutral or in posterior tilt.

Hip and knee joints hyperextended.

Where subject stands predominantly on one leg pelvis will be tilted down to non-favoured side.

Favoured leg appears longer in standing only

#### Elongated and weak

One joint hip flexors. External oblique. Upper back extensors. Neck flexors. Where one leg is faboured, gluteus medius (especially posterior fibres) on favoured side

#### Short and strong

Hamstrings. Upper fibres and Internal oblique.

Low back musculature short but not strong.

Where one leg is favoured, tensor fascia lata is strong and illotibial band is tight on ravoured side.



#### (d) Flat Back

Body segment alignment

Loss of lordosis with pelvis in posterior tilt.

Hip and knee joints hyperextended.

Forward head posture with increased flexion to upper thoracic spine

Elongated and weak

One joint hip flexors

Short and strong

Hamstrings

Abdominals may be strong, with back muscles slightly elongated

Figure 1 (continued). Standing postural patterns from Kendall, McCreary, and Provance (1993) as modified by Norris (Norris, 1995).

In the athletic training setting, hamstring stretching is frequently used as a rehabilitation tool for chronic low back pain because it is believed that this technique reduces pain producing postural imbalances. Although there are many scientific studies or theories which show relationships between chronic low back pain and postural imbalances (e.g., lumbar lordosis, kyphosis, scoliosis, sway back, and flat back), these relationships have not been sufficiently supported (Nourbakhsh & Arab, 2002). In fact, Harreby et al. (1999) and Tafazzoli and Lamontagne (1996) concluded that there was no relationship between low back pain and hamstring length. In addition, there is a paucity of literature on the effectiveness of flexibility training, especially hamstring stretching, to mitigate the mechanical causes of low back pain in spite of frequent clinical application of hip joint muscle stretching.

Review of Literatures that Examined the Postural Models Described by Kendall,

McCreary, and Provance

Several studies have tried to explain the relationships of postural models described by Kendall, McCreary, and Provance (1993). Gajdosik, Albert, and Mitman (1994) studied relationships among hamstring tightness, pelvic tilt, and lumbar and thoracic angles in standing posture. Thirty nondisabled and non-obese males participated

in this study. Pelvic tilt, lumber angle, and thoracic angle were measured in two different positions (i.e., static standing and toe-touch position in standing) to study the effects of hamstring length in the two positions. Pictures were taken by a still camera and these angles were measured on the pictures with a protractor. There were no significant differences in the two positions between pelvic tilt, lumbar angle, and thoracic angle with respect to differences in hamstring muscle length. Gajdosik, Albert, and Mitman (1994) concluded the length of the hamstrings had limited effect on these angles.

A research study conducted by Li, McClure, and Pratt (1996) evaluated the relationships among hamstring stretch, lordosis, and pelvic tilt in a standing position and during partial and full forward bending by using a three-dimensional digitizer. Thirty nine volunteers without musculoskeletal impairment in the spine and lower extremities and with tight hamstring muscles participated in the study. Hamstring length had no significant relationships with lumbar lordosis (r = -.11) and with pelvic tilt (r = .277).

Nourbakhsh and Arab (2002) studied the relationships between low back pain and mechanical factors, including pelvic tilt and hip muscle flexibility. They recruited 600 participants 20 to 65 years of age. The participants were categorized into four groups, 150 asymptomatic men; 150 asymptomatic women; 150 men with low back pain; and 150 women with low back pain. The pelvic tilt of the subjects in a static standing posture

was measured with an inclinometer. Hip flexor muscle length was measured by the Thomas test with a manual goniometer. Hamstrings muscle length was measured by the active knee extension test (90/90 hamstrings test) with a manual goniometer. There were no significant relationships between hamstring length and pelvic tilt (r = .08) and between hamstring length and the size of lumbar lordosis (r = .11). No relationships were found between one-joint hip flexor length and the size of lumbar lordosis (r = .05) and between one-joint hip flexor length and pelvic tilt (r = .07).

Youdas, Garrett, Harmsen, Suman, and Carey (1996) studied the relationship between pelvic tilt and lumbar lordosis in healthy adults. The participants were 90 asymptomatic volunteers (45 males and 45 females) between 40 and 69 years of age. Pelvic tilt in a static standing posture was measured with an inclinometer. Lumbar lordosis in a static standing posture was measured with a specific tool, called a flexible curve. No significant relationship between pelvic tilt and lumber lordosis (r = .06 for males and r = .08 for females) was found.

Youdas, Garrett, Egan, and Therneau (2000) studied relationships between lumbar lordosis and pelvic tilt among people with or without low back pain. Sixty volunteers (30 males and 30 females) between 40 and 69 years of age with chronic low back pain participated in this study. These participants were compared with participants

without low back pain, who were taken from previously published data by Youdas, Garrett, Harmsen, Suman, and Carey (1996). The same measurement protocols described by Youdas, Garrett, Harmsen, Suman, and Carey (1996) were used for pelvic tilt and lumbar lordosis measurements. Correlation coefficients between pelvic tilt and lumbar lordosis among low back pain participants were r = .31 for males and r = .37 for females. Neither the female nor male participants with chronic low back pain demonstrated an increased lumbar lordosis and pelvic tilt compared with participants without low back pain.

#### Significance of Problem

The results of all of these studies did not support the relationships between hip muscle tightness and postural imbalances contended by Kendall, McCreary, and Provance (1993). The use of hip muscle stretching as a rehabilitation tool for chronic low back pain based on these postural models may be a questionable practice, since the results of these studies did not support relationships between hip muscle length, postural imbalances, and low back pain. Health care providers, who attempt to reduce and alleviate low back pain in their patients, should be provided with the scientific understanding for the mechanisms

of low back pain as a basis for their treatment and not be encouraged to rely upon unsubstantiated models.

Need for Study of Thigh Alignment and Hip Angle in Quiet Standing Posture

Research studies (Gajdosik, Albert, & Mitman, 1994; Li, McClure & Pratt, 1996; Nourbakhsh & Arab, 2002; Youdas et al, 1996; Youdas et al, 2000) that have attempted to find relationships between pelvic tilt and hip muscle length have not shown significant relationships. However, these research studies, related to the postural model of Kendall, McCreary, and Provance (1993), are limited to the study of single relationships between (a) hamstring tightness and pelvic tilt, (b) hamstring tightness and lordosis, and (c) pelvic tilt and low back pain in attempting to explain whole body mechanics.

Pelvic tilt does not occur without accompanying movements of the sacrum and femur. In the sagittal plane, the hip joint consists of the innominate and femur with the greater trochanter as the axis of the movement (Figure 2). The hip joint angle is an angle between the innominate and the femur. The innominate does not move independently. It moves relative to the sacrum and femur. Previously referenced researchers, who challenged postural models described by Kendall, McCreary, and Provance (1993), only focused on pelvic tilt without considering accompanying movements of the sacrum,

femur, or both. Additionally, these researchers considered the femur to be aligned vertically in the sagittal plane without the possibility that it could be tilted. However, the femur could also be tilted such that its head is either anterior or posterior to its condyles. When the pelvis tilts, either forward (or anterior) or backward (or posterior), other parts of the body must simultaneously move. Therefore, to more fully understand relationships between hip muscle length and pelvic tilt, alignment of the femur must also be considered. In addition, variation of position of the pelvis results in changes in the alignment of the spine (Jackson, & McManus, 1994; Kendall, McCreary, & Provance, 1993; Levine & Whittle, 1996; Nourbakhsh & Arab, 2002; Youdas et al., 2000). For example, excessive pelvic tilt has an association with lumbar lordosis (Magee, 2002).

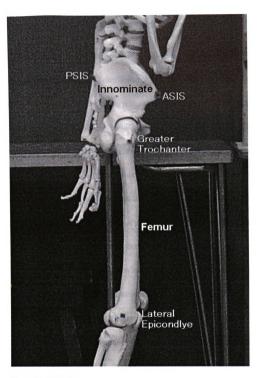


Figure 2. Hip joint.

When changes occur in alignment and positioning of body parts, there are accompanying changes in the mass distribution of the body and associated positioning of the center of pressure. In a quiet standing posture, the body's center of mass and center of pressure move in phase with one another in the same direction (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998). Therefore, the position of the center of pressure in the transverse plane provides an indirect measure of the position of the center of mass in this same plane. Similarly, the center of pressure location, with respect to the lateral malleolus, may be a tool to help in the understanding of postural relationships. In quiet standing, the center of mass and center of pressure are affected by alignments of lower extremity joints including the hip, knee, and ankle. Changes in the angle of the hip joint can change the curvature of the lumbar spine and simultaneously change the position of the body's center of gravity and center of posture (Bot, Caspers, Van Royen, Toussaint, & Kingma, 1999). Therefore, measuring the relative location of the center of pressure with respect to the lateral malleolus may help to explain the position of the center of mass and indirectly provide information about the position of the hip joint.

Postural models described by Kendall, McCreary, and Provance (1993) attempted to explain postural differences from a biomechanical point of view. Many researchers (Lee, Lee, Kim, Hong, & Yoo, 2001; Mulhearn & George, 1999; Youdas, Garrett, Egan, & Therneau, 2000) stated that postural imbalances may be the result of genetics, muscular imbalance, or the assumption of poor posture of daily life. In addition to biomechanical relationships, other possible factors, such as racial or social differences, should be studied well to understand the differences.

It is believed that there are race differences in standing posture. However, research studies and books, stating these differences, are rare. Kendall, McCreary, and Provance (1993) have stated that Asian people tend to have a specific type of postural pattern that is similar to flat back without having a health problem. Although this relationship in Asian people is a common belief, there is no research that has scientifically demonstrated this.

There were two purposes of this study. First purpose was to study biomechanical relationships among hip muscle length, center of pressure, and pelvic tilt and hip angle with respect to postural imbalance.

Second purpose of this study was to address the issue of differences in quiet standing posture between Caucasian and Eastern Asian males. This study examined another possible source to form postural imbalance, in addition to the biomechanical relationships. Genetic and social variations may be possible sources of the variability for racial differences in quiet standing posture examined by pelvic tilt and thigh alignment. A single factor such as hip muscle length may not explain these differences.

Information gained from this study could potentially help athletic trainers and other health care workers decide whether or not hip joint muscle stretching; especially the hamstrings, one-joint hip flexor (iliopsoas) and two-joint hip flexor (rectus femoris) is an appropriate rehabilitation technique to treat low back pain. In addition, this study could provide broader knowledge about posture by examining the race differences as well as biomechanical differences.

#### Hypotheses

Based on the literature review, two hypotheses were determined for the current study:

- 1. In quiet standing posture, hip angle and anterior-posterior position of the hip (as determined by the relative position of the center of pressure) as well as pelvic tilt have relationships with hip muscle length (one-joint hip flexor length, two-joint hip flexor length, and hip extensor length) among college-aged males.
- 2. Pelvic tilt, hip angle, and hip muscle length (one-joint hip flexor length and hip extensor length) have no differences between college-aged Caucasian and Eastern Asian males.

#### Definitions of Terms

The following terms are defined as they apply in this study:

90/90 hamstring test – This is a broadly accepted test, in clinical settings, used to measure hamstring (hip extensor) length (Figure 11). In this position, a participant attempts to extend the knee joint as much as possible. An angle formed by a line connecting the lateral malleolus and lateral epicondyle of the femur and a line connecting the lateral epicondyle and the greater trochanter of the femur is measured by a manual

goniometer (Figure 12). The maximum knee angle is used to define relative hip extensor muscle length.

<u>Center of pressure</u> – This is a displacement measure in the transverse plane at the ground level that represents the location of the vertical ground reaction force vector obtained from a force platform (Winter, 1990).

<u>Flat back</u> – This is type of postural malalignment in which the spine is straight through the inferior thoracic to lumbar areas with accompanying posterior pelvic tilt (Kendall, McCreary, & Provance, 1993) (Figure 1).

Forward and Backward Pelvic tilt – Forward (or anterior) pelvic tilt occurs when the anterior superior iliac spine (ASIS) is displaced forward and inferior from a neutral position of the pelvis and the pubic symphysis is displaced backward (posterior).

Backward (or posterior) pelvic tilt occurs when the ASIS is displaced backward and superior from a neutral position of the pelvis and the pubic symphysis is displaced forward (anterior) (Kendall, McCreary, & Provance, 1993).

Hip flexors – These are muscles, whose active shortening, result in flexion of the hip joint. Examples include the iliopsoas (iliacs and psoas major), pectineus, adductor brevis, and adductor longus defined as one-joint muscles, and the rectus femoris, tensor

fascia latae, and sartorius defined as two-joint muscles (Kendall, McCreary, & Provance, 1993).

Hip angle ( $\theta$ 3) – This is defined as the sum of pelvic tilt ( $\theta$ 1) and thigh alignment ( $\theta$ 2) (Figure 6).

<u>Hip position</u> – This is defined as the anterior-posterior displacement of the hip joint in the sagittal plane.

One-joint hip flexor – The iliopsoas is designated as this type of muscle in the

Thomas test because the lumbar spine is stabilized on a hard and flat surface and the only

movement permitted at the hip joint is in the sagittal plane. Passive tension in the

iliopsoas muscle tends to cause hip flexion against the weight of the lower extremity.

Sway back – This is a malalignment associated with a posterior displacement of the upper trunk and an anterior displacement of the pelvis. There is a backward curve of the spine and a flattening of the lower lumbar region. The pelvis is in posterior tilt and the hip joints are extended. The head and neck are in a forward head position (Kendall, McCreary, & Provance, 1993) (Figure 1).

Thigh alignment ( $\theta$ 2) – This is the orientation of the thigh as determined by a line connecting the greater trochanter and lateral epicondyle of the femur and a vertical line passing through the greater trochanter (Figure 6).

Thomas test – This is a broadly accepted test, in clinical settings, used to differentiate between tightness of the iliopsoas muscle group (one-joint hip flexor) and tightness of the rectus femoris muscle (two-joint hip flexor) (Starkey & Ryan, 1996)

(Figure 7). Angles of the hip and knee are measured by a manual goniometer. The measured hip angle represents one-joint hip flexor length and the measured knee angle represents two-joint hip flexor length (Kendall, McCreary, & Provance, 1993) (Figure 7).

Two-joint hip flexor – The rectus femoris is designated as this type of muscle in the Thomas test. It crosses both the hip and knee joints. Tension in this muscle resists hip extension and knee flexion.

#### **CHAPTER 2**

#### **METHODS**

#### **Participants**

Since sample size is important in MANOVA, it was explored using a method proposed by D'amico, Neilands, and Zambarano (2001). By using SPSS and data values from a similar research (Nourbakhsh & Arab, 2002), the sample size for the current study was determined. The SPSS analyses indicated that more than 20 participants for each independent variable (Caucasian and Eastern Asian groups) was a sufficient sample size. This sample size was approximated in the current study.

Participants were recruited by using flyers (Appendix A) and email lists. The flyers were posted on campus sites at Michigan State University (MSU) frequented by students. The email lists were used to recruit Eastern Asian participants and composed of the same information as the flyers. Emails were sent to lists of international students in College of Education at MSU, Chinese Students and Scholars Association at MSU, and Japanese Club at MSU. Each participant received 10 dollars for his involvement in the study.

Thirty-nine college males, between the ages of 19 and 35 years (M= 25.36 yrs,

SD = 4.39), participated in this study. Participants included 21 Caucasians (M= 22.43 yrs, SD = 1.94) and 18 Eastern Asians (M= 28.78 yrs, SD = 3.95) composed of Chinese, Koreans, and Japanese. Each participant was informed of the experimental procedure and signed an informed consent form (Appendix B) prior to the participation.

All participants answered a short survey (Appendix C) which asked if they had ever been diagnosed by a physician with a severe injury related to the pelvis, spine, and lower extremity. As a result of this survey, it was determined that all participants had no diagnosed history of serious injuries related to the pelvis, spine, and lower extremity. In addition, the Eastern Asian participants did not have ancestors from other ethnic origins. The mean age, height, mass, and BMI of the participants in each group are shown in Table 1 and the data set for all participants is included in Appendix D.

Table 1
Descriptive Statistics of Participants (Mean ± Standard Deviation)

	Total $(n = 39)$	Caucasian $(n = 21)$	Eastern Asian (n = 18)
Age (year)	$25.36 \pm 4.39$	$22.43 \pm 1.94$	$28.78 \pm 3.95$
Height (cm)	$175.2 \pm 6.90$	$177.3 \pm 8.24$	$172.8 \pm 3.88$
Weight (kg)	$74.99 \pm 11.99$	$79.51 \pm 12.86$	$69.71 \pm 8.49$
BMI	$24.38 \pm 3.28$	$25.26 \pm 3.44$	$23.36 \pm 2.84$

#### Instrumentation

Colored adhesive tape was attached to a point on the compressive shorts, worn by the participants, directly over their palpated greater trochanter of the femur or on their skin over other body landmarks, (i.e., anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), lateral epicondyle of the femur, and lateral malleolus of the fibula) (Figure 3). A small dot was marked on each piece of tape to more precisely define each bony landmark. These dots on the colored tapes were used for angle measurements in all tests to identify specific locations of the landmarks. This author, with several years of experience in the study and practice of athletic training, performed all palpations and subsequent placement of tape markers and dots.

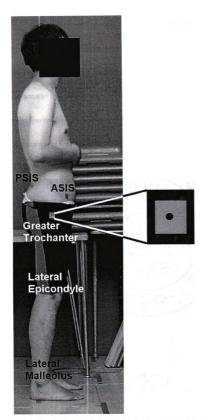


Figure 3. Subject wearing compressive shorts in a quiet standing posture, with colored adhesive tapes and small dots identifying body landmarks.

A manual goniometer with 12 inch arms (Figure 4) was used for angle measurements in the Thomas test (Figure 7) and 90/90 hamstring test (Figure 11). Two 30 cm plastic rulers were aligned with and attached to the arms of the goniometer to extend the arms so that they could cover the entire length of the lower extremity of the participants. For the Thomas test, a bubble balance was aligned with and attached to one of the arms of the goniometer to determine the horizontal line.

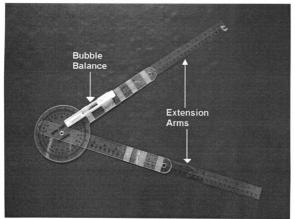


Figure 4. Manual goniometer with a bubble balance and two 30 cm extension arms added.

A digital camera (DSC-P2, SONY Corporation, Tokyo, Japan), with 1600x1200 pixel density, was set on a tripod with the optic axis of its lens one meter above the ground and six meters away from the force platform, where participants were to assume a quiet standing position. The horizontal and vertical orientations of the camera relative to the ground were carefully set using the bubble balances built into its tripod. The captured digital images were transported to Microsoft Photo Editor software to identify Cartesian coordinate locations of bony landmarks (i.e., ASIS, PSIS, greater trochanter and lateral epicondyle of the femur, and lateral malleolus of the fibula) of the participants as pixels on a computer screen. Cartesian coordinates from the digital images were subsequently used to measure pelvic tilt and thigh alignment (Figures 3 and 6).

For each participant, the center of pressure in a quiet standing posture was measured by an AMTI force platform (AMTI, Watertown, MA). APAS system (Ariel Dynamics, Inc., San Diego, CA) software quantified the data obtained from the force platform. Anterior-posterior displacement of center of pressure in the saggital plane was measured in meters at the ground level relative to the horizontal coordinate of the right lateral malleolus. Vertical ground reaction force (Fz) and lateral moment (My) was sampled at 50 Hz over a 7 second time period using the AMTI force platform and APAS software. Five seconds of data (i.e., from 1 to 6 seconds) of the 7 second time period was

used for the calculation of the center of pressure. Anterior-posterior displacements of the center of pressure were obtained by the following formula (Shimba, 1984):

Center of pressure = 
$$My/Fz$$

and the average value over the 5 second period (250 samples) was defined as the center of pressure value.

Average Center of Pressure 
$$= \sum_{i=51}^{300} \left[ \frac{Myi/Fzi}{250} \right]$$

#### Research Design

Six dependent variables for hypothesis 1 included: (a) pelvic tilt in quiet standing posture (in degrees); (b) hip angle in quiet standing posture (in degrees); (c) horizontal displacement in the saggital plane of center of pressure (in meters) in quiet standing posture relative to the lateral malleolus; (d) hip extensor (hamstring) length (in degrees); (e) one-joint hip flexor length (in degrees); and (f) two-joint hip flexor length (in degrees). All dependent variables were continuous scores and ratio scales. Twelve pairs of selected Pearson product moment correlation coefficients were calculated for the six dependent variables. In addition, for each of these selected pairs, coefficients of determination were obtained to test the degree of these relationships.

For hypothesis 2, a multivariate analysis of variance (MANOVA) was used to examine the relationships of race (Caucasian and Eastern Asian males) to four dependent variables: pelvic tilt, hip angle, hamstring length, and one-joint hip flexor length. All dependent variables were continuous scores and ratio scales. The independent variable was race, which was a nominal scale. ANOVA was calculated on two of the four dependent variables (hip extensor length and one-joint hip flexor length). The level of significance was set at p < .05.

Validity of the testing was controlled by subject selection procedures and timing of the administration of a questionnaire. Participants were asked to answer a short survey about their ethnic origin and injury history related to the pelvis, spine, and lower extremity. Participants answered the survey at the end of the experimental sessions so that they did not focus on controlling their posture and testing performance because of related a priori questions.

Pilot study was performed for all measurements (pelvic tilt, hip angle, center of pressure, one-joint hip flexor length, two-joint hip flexor length, and hip extensor length) by this author. Three participants were recruited for this pilot study. All of them had two experimental sessions. The interval between each experimental session had at least two

days. Correlation coefficients between measures made at the first and second sessions were r = .849 for pelvic tilt, r = .933 for hip angle, r = .963 for one-joint hip flexor length, r = .699 for two-joint hip flexor length, and r = .738 for hip extensor length. Results of the pilot study are shown on Table 2.

Table 2
Pilot Study for Measurements

Participants		Sta	nding Po	sture	Thom	90/90	
						Hamstring	
	Session	Pelvic	Hip angle (deg)	Center of pressure (m)	One-joint	Two-joint	Hip
		tilt			hip flexor	hip flexor	extensor
		(deg)			length	length	length
					(deg)	(deg)	(deg)
Α	1	10	186	.064053	183	109	162
	2	10	189	X	185	103	162
В	1	14	196	.052882	168	90	161
	2	21	206	.093454	170	90	160
С	1	15	194	.04584	169	96	153
	2	17	197	.060566	175	104	165
Correlation coefficient - r		.849	.933		.963	.699	.738

#### **Procedures**

Each participant experienced one measurement session. Each session was directed by this author. Each session was conducted in a locked setting opened only to the participant, an assistant experienced at collecting center of pressure data via force platform, and this author to protect the participant's privacy and to remove any effect from extraneous individuals. The experienced assistant stayed in a separate room to collect data for the center of pressure at the same times this author took pictures for pelvic tilt and hip angle measurements.

The order of testing within each session was as follows:

- 1. informed consent (Appendix B);
- 2. height and weight measurements;
- 3. three to five minutes for warm-up on a stationary bike;
- 4. pelvic tilt, hip angle, and center of pressure digital picture in a static quiet standing posture;
- 5. Thomas test;
- 6. 90/90 hamstring test; and
- 7. short survey about injury history and ethnic origin (Appendix C).

All angle measurements (i.e., pelvic tilt, hip angle, Thomas test, and 90/90 hamstring test) were made on the right side of the participants' body. For these measurements, the participants only wore compressive type shorts (Figure 3).

The experimental session started with an informed consent. All participants read and signed the informed consent form and were given time to ask questions about this study.

Height was measured with a stadiometer. The stadiometer had two meters of length and the increments of the measurement were one millimeter. A participant stood barefoot on the floor facing away from the wall. The feet were together and parallel to each other. The heels, buttocks, and upper back touched the wall, which was at a right angle to the floor. The head was positioned in the Frankfort plane line connecting the eye and ear on the horizontal plane. The stadiometer was positioned parallel to the wall in the mid-frontal plane and perpendicular to the floor. The sliding bar of the stadiometer was brought down on the vertex of the head with sufficient pressure to depress the hair. After this position was established, height was measured.

Weight was measured with a platform scale that had a balancing beam, with two movable weights and one tare-screw weight. The increments of the measurements were 0.1 pound. The participant was only allowed to wear compressive shorts during the

measurement. The participant stood on and faced the scale. In this position, weight was measured. The measured value was divided by 2.2046 to convert the English value (pound) to metric value (kilogram).

Before starting the angle measurements, the participants warmed up by engaging in light aerobics exercise, for 3 to 5 minutes, using a stationary bike so that all participants would experience a similar pre-measurement preparation.

Adhesive tapes were directly placed on bony landmarks or on the cloth of the compressive shorts directly above the greater trochanter. The landmarks included the most anterior aspect of the ASIS, the most posterior aspect of the PSIS, the most lateral aspect of the greater trochanter, the most lateral aspect of the lateral epicondyle of the femur, and the most lateral aspect of the lateral malleolus. On the adhesive tapes, small dots were marked by a permanent marker to identify the specific point locations of the bony landmarks (Figure 3). The landmarks were determined by palpation by this author.

Pelvic Tilt, Hip Angle, and Center of Pressure. To measure pelvic tilt, hip angle, and center of pressure, each participant was asked to stand barefoot on a force platform so that the right side of the body faced toward the digital camera. A line formed by the alignment of the lateral malleolus of each lower extremity was parallel to the optic axis of

the lens of the digital camera and was at a right angle to the anterior-posterior axis of the force platform (Figure 5). The digital camera was placed so that the optic axis of its lens was one meter above and parallel to the ground and the perpendicular distance of the center of its lens was six meters from a vertical plane passing through the right lateral side of the force platform. This arrangement maximized the size of the subjects in the field of view of the camera. The participants were assisted in setting the width of their lateral malleoli the same as the width of their greater trochanters so that both the greater trochanters and lateral malleoli were on the same vertical planes. After determining the feet position, the participants were asked to stand as natural and comfortable as possible (i.e., quiet standing posture) while maintaining the designated body orientation and malleoli alignment with respect to the digital camera and force platform. The participants were asked to maintain this position for approximately 10 seconds. During this time, the force platform and the APAS software were used to record Fz and My for 7 seconds. During the middle of the time interval, a picture was taken by the digital camera. In case that the locations of the bony landmarks were blocked by the right hand, the hand was placed on the stomach only to take a picture by the digital camera (Figure 3). The participants were instructed so that they did not change alignment of quiet standing posture. The right hand was not moved when recording the center of pressure.

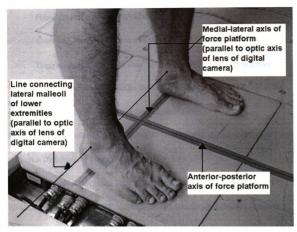


Figure 5. Orientation of the malleoli and force platform with respect to the optic axis of lens of digital camera.

Pelvic tilt ( $\theta$ 1) and hip angle ( $\theta$ 3) (Figure 6) were calculated by using Cartesian coordinate values of selected pixels representing bony landmarks (i.e., ASIS, PSIS, greater trochanter, lateral epicondyle of the femur) from a digital picture of the participants displayed on a computer screen. Pelvic tilt was defined as the angle formed by a line connecting the ASIS and PSIS and a horizontal line passing through the ASIS. It was calculated using the following trigonometric function.

Pelvic Tilt  $(\theta 1) = \tan^{-1} \{ (Ay-Py)/(Ax-Px) \}$  (in degrees),

where the Cartesian coordinates for ASIS = Ax, Ay and PSIS = Px, Py.

Thigh Alignment ( $\theta 2$ ) = 180 - tan<sup>-1</sup>{(GTx-LEx)/(GTy-LEy)} (in degrees),

where Cartesian coordinates for the greater trochanter = GTx, GTy, and lateral epicondyle = LEx, LEy (See section on Definitions of Terms.).

Hip angle ( $\theta$ 3) was defined as sum of pelvic tilt ( $\theta$ 1) and thigh alignment ( $\theta$ 2) (See section on Definitions of Terms.).

Hip Angle ( $\theta$ 3) = Pelvic Tilt + Thigh Alignment=  $\theta$ 1 +  $\theta$ 2 (in degrees).

Alviso, Dong, and Lentell (1988) investigated the intertester reliability of a method to measure angle of pelvic tilt. Six physical therapists measured the angles of pelvic tilt of twelve participants (six males and six females) in a relaxed position. The participants actively tilted the pelvis anteriorly and posteriorly. Testers used depth calipers, modified meter stick and adhesive markers and used a trigonometric equation to determine the angle of pelvic tilt. The authors indicated that there were good intertester reliabilities (r = .88 to .95 for six different measurements). Gajdosik, Simpson, Smith, and DonTigny (1985) examined intratester reliability of a test designed to measure the standing pelvic-tilt angle, active posterior and anterior pelvic-tilt angles and ranges of motion, and the total pelvic-tilt range of motion (ROM). The pelvic-tilt angles of the right side of 20

men were calculated using trigonometric functions. Intratester reliability coefficients

(Pearson r) for test and retest measurements were .88 for the standing pelvic-tilt

angle, .88 for the posterior pelvic-tilt angle, .92 for the anterior pelvic-tilt angle, .62 for the posterior pelvic-tilt ROM, .92 for the anterior pelvic-tilt ROM, and .87 for the total ROM.

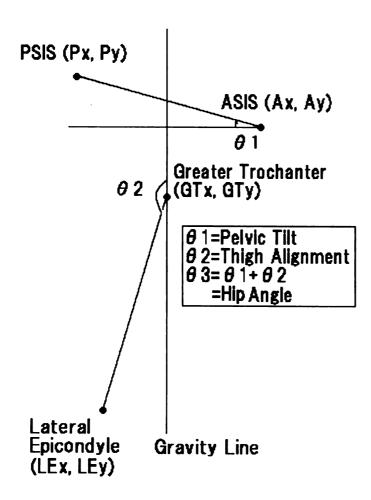


Figure 6. Pelvic tilt, thigh alignment, and hip angle.

One- and Two-Joint Hip Flexor Length Measurements. To measure length of one- and two-joint hip flexors (See section on Definition of Terms), the Thomas test was used (Kendall, McCreary & Provance, 1993) (Figure 7). Gabbe, Bennell, Wajswelner, and Finch (2004) reported inter-rater reliability and test-retest reliability of the Thomas test. Two raters (A and B) measured fifteen participants (six males and nine females) with a manual goniometer. For one-joint hip flexor length measurement, an inter-rater intraclass correlation coefficient (ICC) was .92. Test-retest ICCs were .63 for the rater A and .75 for the rater B. For two-joint hip flexor length measurement, an inter-rater ICC was .90. Test-retest ICCs were .69 for the rater A and .69 for the rater B. Harvey (1998) used the modified Thomas test and obtained measures of flexibility for the iliopsoas, quadriceps and tensor fascia lata/iliotibial band on 117 elite athletes in tennis, basketball. rowing, and running to determine hip muscle length. A manual goniometer was used for measurements. The ICCs for two trials demonstrated high reliability (r = .91 to 94).

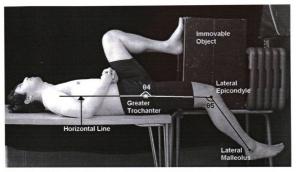


Figure 7. Thomas test with the right lower extremity released and the one- and twojoint hip flexors relaxed.

To accomplish the Thomas test, the participant first lay in a supine position on a table or other hard and flat surface. The participant then flexed both hips and knees to make the lumbar spine and sacrum flat on the surface. Because the most common error of the Thomas test was that the subject fails to maintain the lumbar back in a flat position (Kendall, McCreary, & Provance, 1993), an immovable object was placed so one of its flat surfaces forms a vertical plane in front of the soles of the feet to prevent subsequent forward movement of the feet and tilt of the pelvis. Then, the foot on the side to be measured (right side) was released from the immovable object permitting this lower extremity to extend at the hip and flex at the knee. During this release, the participants

were instructed to maintain a relaxed state in the lower extremity muscles on the side to be measured. Angles of the hip and knee were measured by a manual goniometer. The measured hip angle represented one-joint hip flexor length and the measured knee angle represented two-joint hip flexor length (Kendall, McCreary, & Provance, 1993). With the participant in this relaxed position, one-joint (θ4) and two-joint (θ5) hip flexor length were measured.

One-joint hip flexor length ( $\theta$ 4) was measured with a manual goniometer (See section on Definitions of Terms and Figures 7 and 8). An angle formed by a line connecting the greater trochanter and lateral epicondyle of the femur and a horizontal line passing through the greater trochanter of the femur was designated as  $\theta$ 4.

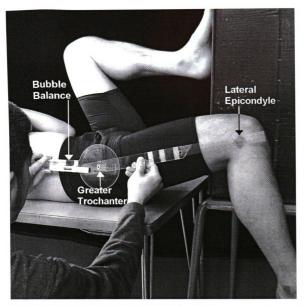


Figure 8. Goniometer placement for one-joint hip flexor length.

The calculation of two-joint hip flexor length ( $\theta$ 6) was used as an indirect representation of the two-joint muscle length. An angle formed by a line connecting the greater trochanter and the lateral epicondyle of the femur and a line connecting the lateral epicondyle of the femur and the lateral malleolus of the fibula was designated as  $\theta$ 5.

Since  $\theta\theta$  was dependent upon a combination of values from both  $\theta\theta$  and  $\theta\theta$  (See section on Definitions of Terms and Figures 7 to 9), there were many possible pairs of values of  $\theta$ 4 and  $\theta$ 5 that could equal a single value of  $\theta$ 6. In general, there were three possible conditions of  $\theta 4$  for the calculation of  $\theta 6$  (Table 3 and Figure 10). Each of these conditions depended on the size of  $\theta 4$  (condition 1:  $\theta 4 < 180$  degrees, condition 2:  $\theta 4 =$ 180 degrees, and condition 3:  $\theta 4 > 180$  degrees). Considering only variations in  $\theta 4$ , in the first condition, the hip joint was in a relatively flexed position because of tightness in the one-joint hip flexor. Therefore,  $\theta$ 5, associated with the two-joint hip flexor, was likely to be relatively small. In condition two (Figure 10), the hip joint was at 180 degrees. Since  $\theta$ 4 has increased with respect to condition 1,  $\theta$ 5 was likely to also increase. Finally, in condition three (Figure 10), 04 was shown to be larger than 180 degrees. Therefore, 05 was likely to be larger than in conditions 1 or 2. For two-joint hip flexor length ( $\theta 6$ ), the smaller angle value was interpreted as better muscle extensibility. Note that the minimum value possible for θ6 in the Thomas test was 90 degrees because (a) it was a gravity dependent test, (b) the participant was not suppose to apply knee flexor muscle contraction, and (c) the table or flat surface was positioned horizontally.

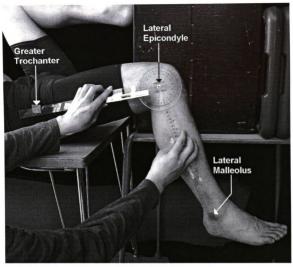


Figure 9. Goniometer placement for two-joint hip flexor length.

Table 3
Calculation of Two-joint Hip Flexor Length (θ6)

Conditions of θ4	Equations for determining θ6 (in degree)*	
θ4 < 180°	θ5 + (180° – θ4)	
$\theta 4 = 180^{\circ}$	θ5	
$\theta 4 \geq 180^o$	$\theta 5 - (\theta 4 - 180^{\circ})$	

<sup>\*</sup>Note that these equations are the same but are written here in a different format to show the influence of  $\theta 4$  on two-joint hip flexor length.

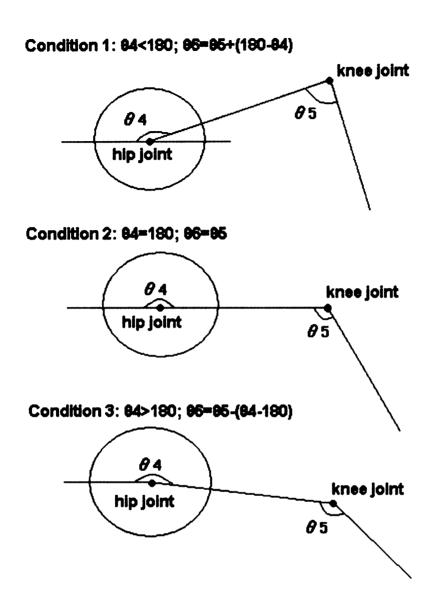


Figure 10. Three general conditions for two-joint hip flexor length  $(\theta 6)$ .

Hip Extensor (Hamstring) Muscle Length Measurement. To test hip extensor (hamstring) muscle length, the 90/90 hamstrings test (active knee extension test) (Figure 11) was used (Konin, Wilksten, & Isear, 1997) (See section on Definitions of Terms and

Figure 11). Gajdosik and Lusin (1983) showed high reliability of this method. The hamstring (hip extensor) muscle length of both extremities of 15 men was measured during test and retest sessions. The ICCs for test and retest measurements were .99 for both the left and right extremities. Gabbe, Bennell, Wajswelner, and (2004) reported inter-rater reliability and test-retest reliability of the active knee extension (90/90 hamstring) test. Two raters (A and B) measured fifteen participants (six males and nine females) with a manual goniometer. An inter-rater intraclass correlation coefficient (ICC) was .93. Test-retest ICCs were .96 for the rater A and .94 for the rater B.

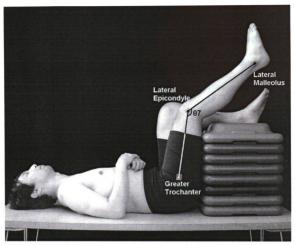


Figure 11. 90/90 hamstring test.

For the 90/90 test (Figure 11), the participant lay in a supine position on a table or other hard and flat surface. The participant then flexed both hips and knees to 90 degrees to position the lumbar spine in a position flat on the table and the posterior surfaces of the calves on a bench or other adjustable object that helped to maintain a right angle at the knees and hips. Next, the knee on the side to be measured was actively extended as much as possible by the participant via knee extensor muscle contraction

while maintaining the hips at 90 degrees and the knee on the opposite side at 90 degrees.

An angle formed by a line connecting the lateral malleolus and lateral epicondyle of the femur and a line connecting the lateral epicondyle and the greater trochanter of the femur was measured by a manual goniometer (Figure 12). This angle (07) was used to define hamstring length.

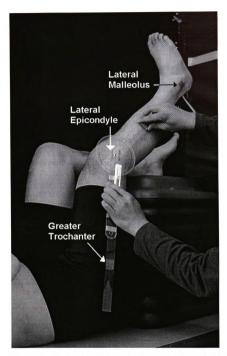


Figure 12. Goniometer placement for hip extensor (hamstring) length.

Short Survey. The participants were asked to answer a short survey (Appendix C). The survey asked questions about ethnic origin and injury history. Ethnic origin was asked because the current study was limited to participants who were Caucasians and who were Eastern Asians. Participants who had ever been diagnosed by a physician with a severe injury of the pelvis, spine, or lower extremity were also excluded from participation in this study. This survey was administered after all physical measurements and tests to remove its potential effect on how the participants performed.

UCRIHS Approval. The current study was approved by the University

Committee on Research Involving Human Subjects (UCRIHS) at Michigan State

University on June 2004. The revisions about the intensive and informed consent were approved on July 2004. The approval letters are shown in Appendix E and F.

### **CHAPTER 3**

## **RESULTS**

Raw data for six dependent variables are shown in Appendix G. The means and standard deviations of the tested variables are shown in Table 4.

Table 4
Descriptive Values and F-values of the Tested Variables

	Total	Caucasian	Eastern Asian	F-	p
	Population	(n = 21)	(n = 18)	value	•
	(n = 39)				
Pelvic Tilt (θ1)	$16.90 \pm 4.31$	$16.90 \pm 5.06$	$16.91 \pm 3.37$	.000	.994
(deg)					
Hip Angle (θ3)	$196.46 \pm 5.18$	$196.35 \pm 6.51$	$196.58 \pm 3.18$	.019	.891
(deg)					
One-Joint Hip	$183.64 \pm 7.26$	$185.10 \pm 6.91$	$181.94 \pm 7.49$	1.867	.180
Flexor Length (θ4)					
(deg)					
Two-Joint Hip	$110.00 \pm 9.96$	$108.00 \pm 9.35$	$112.33 \pm 10.40$	-	-
Flexor Length (θ6)					
(deg)					
Hip Extensor Length	$153.21 \pm 9.08$	$153.62 \pm 9.64$	$152.72 \pm 8.63$	.092	.763
$(\theta 7)$ (deg)					
Center of Pressure	$0.062 \pm 0.020$	$0.056 \pm 0.015$	$0.068 \pm 0.024$	-	-
(m)					

Table 5 presents selected correlation coefficients and coefficient of determination between six variables. The results revealed that a relationship between pelvic tilt ( $\theta$ 1) and hip angle ( $\theta$ 3) was significant (r = .896, p < .01) and a relationship

between pelvic tilt ( $\theta$ 1) and two-joint hip flexor length ( $\theta$ 6) was significant (r = .299, p < .05). There were no other significant relationships at p < .05 or < .01 levels. Pelvic tilt ( $\theta$ 1) had no significant relationships with other variables except for relationships with hip angle ( $\theta$ 3) and two-joint hip flexor length ( $\theta$ 6). Hip angle ( $\theta$ 3) and Two-joint hip flexor length ( $\theta$ 6) had no significant relationships with other variables except for relationships with pelvic tilt ( $\theta$ 1). One-joint hip flexor length ( $\theta$ 4), hip extensor length ( $\theta$ 7), and center of pressure had no significant relationships with other variables.

Table 5
Correlation Coefficients and Coefficient of Determination between Variables

Variables	Pelvic Tilt	Hip Angle Filt (03)		Hip I	One-Joint Hip Flexor		Two-Joint Hip Flexor		Hip Extensor		Center of Pressure	
	<u>(01)</u>				Length (θ4) CC CD		Length (θ6)		Length (θ7)		CC CD	
		CC	CD		CD	СС	CD	CC	CD		СБ	
Pelvic Tilt (θ1)	X	.896†	.803	131	.0172	.299‡	.0894	010	.000100	018	.000324	
Hip Angle												
(θ3)			X	057	.00325	.161	.0259	098	.00960	039	.00152	
One-Joint Hip Flexor Length (04)					X					146	.0213	
Two-Joint Hip Flexor Length (θ6)						х	ζ			.145	.0210	
Hip Extensor Length (θ7)									x	.115	.0132	
Center of Pressure											X	

CC = Correlation coefficients.

CD = Coefficient of determination.

<sup>†</sup>*p*<.01.

<sup>‡</sup> *p*< .05.

The MANOVA results (Table 4) indicated that there was no significant difference between the Caucasian and Eastern Asian males relative to the four dependent variables (i.e., pelvic tilt, p = .994; hip angle, p = .891; one-joint hip flexor length, p = .180; and hip extensor length, p = .763). Subsequently, ANOVA was calculated on two of the four dependent variables (hip extensor length and one-joint hip flexor length). ANOVA was not calculated for pelvic tilt and hip angle, because values of hip angle were included in values of pelvic tilt. This also resulted in no significant differences of hip muscle length (one-joint hip flexor length and hip extensor length) between Caucasian and Eastern Asian males.

#### **CHAPTER 4**

#### **DISCUSSIONS AND IMPLICATIONS**

Hypothesis 1

The following is a modified restatement of hypothesis 1. In quiet standing posture, hip angle and anterior-posterior position of the hip (as determined by the relative position of the center of pressure) as well as pelvic tilt have relationships with one-joint hip flexor length and two-joint hip flexor length (as measured by the Thomas test), and hip extensor length (as measured by the 90/90 hamstring test) among college-aged males.

The relationships between pelvic tilt and hip angle and between pelvic tilt and two-joint hip flexor length were the only significant correlations (i.e., there were no significant relationships between pelvic tilt, hip angle, one-joint hip flexor length, two-joint hip flexor length, hip extensor length, and center of pressure).

In comparison to previous studies (Gajdosik, Albert, & Mitman, 1994; Li, McClure & Pratt, 1996; Nourbakhsh & Arab, 2002; Youdas et al, 1996; Youdas et al, 2000), the current study added hip angle as a variable because the one- and two-joint hip flexors, and hamstrings have their insertions on the femur. However, the hip joint consists

of the innominate, femur, with the greater trochanter as the axis of rotation. A significant relationship (r = .896, p < .01) between pelvic tilt and hip angle was found. This result indicates that larger pelvic tilt is associated with larger hip angle and smaller pelvic tilt is associated with smaller hip angle. However, this high correlation might not have a significant meaning because pelvic tilt ( $\theta 1$ ) is imbedded in the value of for hip angle (i.e., hip angle =  $\theta 3 = \theta 1 + \theta 2$ ). Since the variability of  $\theta 1$  is relatively large (from 9.62 to  $\theta 1 = \theta 1 = \theta$ 

Because a relationship between pelvic tilt and hip angle can be primarily explained by imbedding of pelvic tilt in the value of hip angle, even though there was a high correlation between the two variables, its support for hypothesis 1 is very limited. In addition, the low correlation (r = .299) between pelvic tilt and two-joint hip flexor length does not provide strong support for hypothesis 1. In summary, two significant correlations do not provide strong support for the postural models described by Kendall, McCreary, and Provance (1993). These results supported previous findings of no

significant relationships between hamstring tightness and pelvic tilt (Gajdosik, Albert, & Mitman, 1994; Li, McClure, & Pratt, 1996) and between pelvic tilt and hip muscle flexibility (Hellsing, 1988; Nourbakhsh & Arab, 2002).

The current study also measured the location of the body's center of pressure relative to the lateral malleolus and hip angle that were not selected as variables in similar research studies. From center of pressure calculations a relationship between (a) center of pressure distance from the lateral malleolus and pelvic tilt and (b) center of pressure distance from the lateral malleolus and hip angle were expected to be found because center of mass is affected by movements of lower extremity joints (Bot, Caspers, Van Royen, Toussaint, & Kingma, 1999). In addition, center of pressure distance from the lateral malleolus was expected to help explain anterior-posterior positioning of the hip joint. However, no relationships between center of pressure and other variables were found.

Body Mass Index (BMI) was calculated and compared with pelvic tilt to explore another possible source that might influence posture during quiet standing. There was no significant correlation between BMI and pelvic tilt (r = -.0075). Youdas, Garrett, Egan, and Therneau (2000) have also reported that there were no correlations between pelvic tilt and BMI (r = .41 for females and r = .20 for males).

## Hypothesis 2

The following is a restatement of hypothesis 2: Pelvic tilt, hip angle, and hip muscle length (one-joint hip flexor length and hip extensor length) have no differences between college-aged Caucasian and Eastern Asian males.

In the current study no significant differences in pelvic tilt and hip angle in quiet standing posture; one-joint hip flexor length, and hip extensor length were found between Caucasian and Eastern Asian male participants. The results did not support belief that there was a difference in standing posture between Caucasian and Eastern Asian races. In Eastern Asian participants, their standing posture (pelvic tilt and thigh alignment) was not significantly different from the Caucasian participants.

The current study only focused on anterior-posterior or single plane relationships (i.e., sagittal plane relationships) in quiet standing posture. However, hip joint actions occur in three dimensions (i.e., flexion-extension in the sagittal plane, adduction-abduction in the frontal plane, and internal-external rotation in the transverse plane). In the current study the greater trochanter was simply dealt with as the axis of rotation for sagittal plane movement of the femur. However, the hip joint is a ball-and-socket joint in which the head of the femur articulates with the acetabulum of

the innominate. This means that the hip joint does not have an exact and immovable point for joint actions as represented in this study by the greater trochanter. Because the pelvis, spine, and femur engage in three dimensional movements, two dimensional analysis of the movements of the body may not be enough to explain real life movement in this region. Further study should take these factors into consideration.

The current study recruited Caucasian and Eastern Asian male participants so that in addition to hip muscle length race could be explored as a possible variable to influence standing posture. No differences were found in standing posture between Caucasians and Eastern Asians. One possible reason for this result was that the recruited participants may not have been good representatives of their respective races. All participants were recruited in the United States. Differences might have been found if Eastern Asians were recruited in their country of origin because culture may precipitate functional and structural differences in quiet standing posture. In addition to race, the culture in which the participants live over an extended period of time should be considered in future studies.

Kendall, McCreary, and Provance (1993) had stated that Asian people exhibit flat-back posture, different from most American and Europeans, without indicating where they made their observations. The current study did not find any supportable relationships

between variables measured and race of the participants associated with quiet standing posture. The number of participants was minimally enough to study race differences. A much larger population may have helped to elucidate differences.

Kendall, McCreary, and Provance (1993) presented the postural models in quiet standing to show relationships between hip muscle length, standing posture, and low back pain. Many researchers attempted to find the relationships. However, these relationships have not been sufficiently supported. Gaidosik, Albert, and Mitman (1994) concluded that hamstring length had limited effect on pelvic tilt, lumbar angle, and thoracic angle. Li, McClure, and Pratt (1996) reported that hamstring length had no significant relationships with lumbar lordosis (r = -.11) and with pelvic tilt (r = .277). Nourbakhsh and Arab (2002) studied the relationships between low back pain and mechanical factors, including pelvic tilt and hip muscle flexibility. There were no significant relationships between hamstring length and pelvic tilt (r = .08) and between hamstring length and the size of lumbar lordosis (r = .11). No relationships between one-joint hip flexor length and the size of lumbar lordosis (r = -.05) and between one-joint hip flexor length and pelvic tilt (r = .07) were found. Youdas, Garrett, Harmsen, Suman, and Carey (1996) studied the relationship between pelvic tilt and lumbar lordosis in healthy adults. No relationship between pelvic tilt and lumber lordosis (r = .06 for males and r = .08 for females) was

found. Youdas, Garrett, Egan, and Therneau (2000) studied relationships between lumbar lordosis and pelvic tilt among people with or without low back pain. Neither the female nor male participants with chronic low back pain demonstrated an increased lumbar lordosis and pelvic tilt compared with participants without low back pain. Harreby et al. (1999) and Tafazzoli and Lamontagne (1996) concluded that there was no relationship between low back pain and hamstring length.

The current study supported the results of the previous researches in relationships between quiet standing posture and hip muscle length. In addition, the current study demonstrated that racial difference (Caucasian and Eastern Asian males) did not have significant effect on quiet standing posture and hip muscle length. Since posture is a complicated mechanism, differences in posture may not be explained by a single factor. Other reasons such as genetic, social, or geographical differences as well as physical reasons such as skeletal or muscle mass differences should be considered.

#### **CHAPTER 5**

#### **CONCLUSIONS**

There were no relationships between pelvic tilt, hip angle, one- and two-joint hip flexor length, hip extensor length, and center of pressure location relative to the lateral malleolus among Caucasian and Eastern Asian male participants, except for a relationship between pelvic tilt and hip angle. However, this relationship was not clear due to the fact that pelvic tilt was embedded in hip angle. These results were consistent with previous researches that explored relationships between postural imbalances and hip muscle length. No race difference was found in standing posture (pelvic tilt and hip angle) and hip muscle length (one-joint hip flexor length and hip extensor length) between Caucasian and Eastern Asian males. Standing posture in Eastern Asian participants was not significantly different from the Caucasian participants. The results did not support a belief that there were differences in quiet standing posture between races. Posture is a complicated mechanism and not determined by a single factor such as hip muscle length or racial difference.

**APPENDICES** 

APPENDIX A
Flyer to Recruit Participants

# **Research Participants Needed**

Relationships between hip muscle extensibility, hip joint angle, and pelvic tilt in static standing posture among college-aged healthy Caucasian and Eastern Asian

## Eligibility:

- Healthy males (18-30 years of age)
- Caucasian (White) or
- Eastern Asian (Chinese, Korean, Taiwanese, or Japanese)
- No recent history of serious leg and low back injury

#### Measurements:

- Standing posture analysis
- Range of motion of lower extremity
- Weight distribution under feet
- Short survey about national origin and injury history
- Need only one session
- Will take about 20 minutes for each participant

You will receive: \$10 for participation

Location: Biomechanics Research Station (107 IM Circle)

Date: 6/28/04 to 8/6/04, 9am to 6pm

#### Contact:

Toru Tanaka, ATC, CSCS.

Graduate Student in Department of Kinesiology, Email: tanakato@msu.edu

♦ Email or visit Biomechanics Research Station (107 IM Circle) for detail information and scheduling

APPENDIX B
Informed Consent

Consent Form – "Relationships between hip muscle length, hip joint angle, and pelvic tilt in static standing posture among college-aged healthy Caucasian and Eastern Asian males"

The purposes of this study are to understand the 1) relationship between hip joint angle and effect of hip joint muscle flexibility and 2) race differences in standing posture and the possible reasons. It is believed that hip joint muscle flexibility has associations with standing postural patterns and there are differences in standing posture between Caucasian and Asian people. This study will attempt to find their possible explanations by assessing and comparing measurements of physical characteristics.

The data collection session will last approximately 30 minutes and participants will be asked to participate in only one data collection session. Participants should not have any lower extremity injury, low back pain, and extreme postural imbalance. Data collection will have following stages:

- 1. **General information:** You will be given general information about this study and a chance to ask questions.
- 2. **Measurements:** All measurements will be collected in private in the Department of Kinesiology's Biomechanics Research Station located in the IM Sports Circle Building on the campus of Michigan State University.
- Weight will be assessed on a standard weight balance while you are wearing only shorts and t-shirt (tucked into shorts)
- Height will be assessed with a standard stadiometer
- You will be asked to warm up by using a stationary bike in 3 minutes
- A picture in a static and comfortable standing posture will be taken from your right side by using a digital camera. Five colored marks will be placed on your body to identify bony landmarks. The picture will be used to measure angles of pelvic tilt and hip joint.
- Center of pressure will be measured at the same time when you will be taken a picture in standing posture
- Range of motion of your hip flexor and extensor muscles will be measured with a
  mechanical goniometer. You will be asked to perform two different tasks while you
  will lie down on your back on the table.
- 3. Survey: About your origin and injury history
- 4. Payment: You will receive \$10 for your participation

You are asked to participate in this study because you are college-aged healthy Caucasian or Eastern Asian. Your participation is totally voluntary. You may choose to

participate or not and discontinue your participation at any time without any explanation. By participating in this study, you agree that the materials and data generated (picture and measurements) may be used for research and academic purposes. You have also been assured that your privacy will be protected to the maximum extent allowable by law. When this research is completed, an abstract of the results will be emailed to you. You may also seek personal data for comparison to your and other ability and race group.

If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. Financial compensation for lost wages, disability, pain or discomfort is not available. This does not mean that you are giving up any legal rights you may have.

If you have any questions about this study, please contact Dr. Eugene Brown (353-6491, ewbrown@mus.edu) or Toru Tanaka (355-5881, tanakato@msu.edu) at the Kinesiology Department, Michigan State University. If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish- Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subject (UCRIHS) by phone: (517)355-2180, fax: (517)432-4503, email: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Your signature below indicates your voluntary agreement to participate in this study.

Name of Participant:		Signature:	
Date:			
Mailing Address:			
Phone:	Email Address:		
Date of Birth			

APPENDIX C
Short Survey

# Survey Form – "Relationships between hip muscle length, hip joint angle, and pelvic tilt in static standing posture among college-aged healthy Caucasian and Eastern Asian males

1.	Name:
	Age:
	Are youCaucasian orEastern Asian (Chinese, Korean, Taiwanese, or Japanese)?
4.	Do you have an ancestor from other ethnic origin?YesNo If yes, from where?
5.	Have you ever been diagnosed with low back pain?YesNo If yes, when?
6.	Have you ever been diagnosed with lower extremity injury?YesNo  If yes, which body part?  If yes, when?
7.	Have you ever been diagnosed with pubic symphysis, pelvic girdle, or sacrum problems?YesNo If yes, when?
Sig	nature:Date:

APPENDIX D

Descriptive Statistics of Participants

Participants	Age (yrs)	Height (cm)	Weight (kg)	BMI
C1	26	183.6	100	29.67
C2	23	178.9	69.13	21.6
C3	22	167.5	73.39	26.16
C4	22	166.7	69.44	24.99
C5	21	177	94.59	30.19
<b>C6</b>	23	176.2	86.98	28.01
<b>C7</b>	21	179.3	70.12	21.81
C8	25	176.2	83.62	26.94
<b>C9</b>	19	171.8	59.34	20.11
C10	23	183.2	83.26	24.81
C11	21	178.8	98.66	30.86
C12	23	181.2	73.48	22.38
C13	23	183.3	97.85	29.12
C14	22	194.9	97.35	25.63
C15	25	175	72.84	23.79
C16	23	173.8	78.82	26.09
C17	21	159	61.34	24.26
C18	19	179.3	77.15	24
C19	22	193.4	73.84	19.74
C20	21	172.8	61.97	20.75
C21	26	171.2	86.61 29.55	
A1	24	171	64.46	22.05
A2	22	182.1	76.56	23.09
A3	25	175.4	67.04	21.79
A4	28	172.9	66.82	22.35
A5	28	169.2	53.54	18.7
A6	24	171.2	56.63	19.32
A7	30	175	63.33	20.68
A8	29	175	64.78	21.15
A9	24	173.3	72.89	24.27
A10	35	174.3	89.38	29.42
A11	34	169.7	76.65	26.62
A12	26	173	63.96	21.37

<b>Participants</b>	Age (yrs)	Height (cm)	Weight (kg)	BMI
A13	32	167.3	77.83	27.81
A14	32	166.3	68.31	24.7
A15	29	171.4	71.48	24.33
A16	30	177.3	70.85	22.54
A17	34	176.5	78.82	25.3
A18	32	169.2	71.39	24.94
C – Mean	22.43	177.3	79.51	25.26
C – SD	1.938	8.242	12.86	3.439
A – Mean	28.78	172.8	69.71	23.36
A – SD	3.949	3.875	8.484	2.838
TP - Mean	25.36	175.2	74.99	24.38
TP – SD	4.386	6.903	11.99	3.279

C = Caucasian

A = Eastern Asian

TP = Total Population

SD = Standard Deviation

APPENDIX E
UCRIHS Approval Letter

#### MICHIGAN STATE

June 22, 2004

TO: Eugene W. BROWN

204 IM Sports Circle Bldg

RE: IRB# 04-434 CATEGORY: EXPEDITED 2-4, 2-6

APPROVAL DATE: June 8, 2004 EXPIRATION DATEJune 8, 2005

TITLE: Relationships between hip muscle extensibility, hip joint angle, and pelvic tilt in

static standing posture among college-aged healthy Caucasian and Eastern

Asian

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the **UCRIHS approved this project.** 

**RENEWALS:** UCRIHS approval is valid until the expiration date listed above. Projects continuing beyond this date must be renewed with the renewal form. A maximum of four such expedited renewals are possible. Investigators wishing to continue a project beyond that time need to submit a 5-year application for a complete review.

**REVISIONS:** UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please include a revision form with the renewal. To revise an approved protocol at any other time during the year, send your written request with an attached revision cover sheet to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

**PROBLEMS/CHANGES:** Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at (517) 355-2180 or via email: UCRIHS@msu.edu. Please note that all UCRIHS forms are located on the web: http://www.humanresearch.msu.edu

Sincerely,

Peter Vasilenko, Ph.D.

**UCRIHS Chair** 

### APPENDIX F UCRIHS Approval Letter for Revision



July 15, 2004

TO:

Eugene W. BROWN 204 IM Sports Circle Bldg

RE:

IRB # 04-434

**CATEGORY: 2-4, 2-6** 

**EXPEDITED** 

**APPROVAL DATE: EXPIRATION DATE:**  June 8, 2004

June 8, 2005

TITLE:

Relationships between hip muscle extensibility, hip joint angle, and pelvic tilt in static

standing posture among college-aged healthy Caucasian and Eastern Asian

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS APPROVED THIS PROJECT'S REVISION.

**REVISION REQUESTED:** 

July 9, 2004

REVISION APPROVAL DATE: July 9, 2004

Revision to include a change in the subject incentive and consent. The new consent is to replace the current one.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved. If we can be of further assistance, please contact us at (517) 355-2180 or via email: UCRIHS@msu.edu.

Sincerely.

Peter Vasilenko, Ph.D.

Revision

**UCRIHS Chair** 

## APPENDIX G Raw Data for Six Dependent Variables

Participants	Pelvic Tilt 01 (deg)	Thigh Alignment 03 (deg)	One-Joint Hip Flexor Length 04 (deg)	Two-Joint Hip Flexor Length 06 (deg)	Hip Extensor Length 07 (deg)	Center of Pressure (m)
C1	10.06906	188.9501	186	105	162	0.064053
C2	30.96376	216.8253	185	110	149	0.067455
C3	20.28256	200.2826	189	117	157	0.044188
C4	21.69511	201.1695	187	106	163	0.041665
C5	9.619728	187.1516	186	113	140	0.056049
C6	19.24188	195.6971	164	118	176	0.073745
<b>C7</b>	13.87753	198.3853	189	100	160	0.044628
C8	20.73871	204.5027	178	120	143	0.050545
С9	19.65382	198.9494	173	119	158	0.055487
C10	15.61939	194.1813	191	107	146	0.070029
C11	18.13019	198.5998	182	90	150	0.034513
C12	13.59095	194.0664	190	90	154	0.075078
C13	10.26137	188.224	191	108	156	0.035761
C14	18.43495	195.3646	187	95	145	0.069023
C15	17.60463	195.9409	192	98	138	0.034922
C16	17.22344	196.5132	192	112	164	0.058198
C17	15.76718	196.3373	183	113	141	0.03393
C18	18.04782	195.7294	181	122	162	0.073698
C19	11.66877	189.2646	192	104	157	0.054351
C20	11.17384	190.1508	186	108	147	0.084416
C21	21.27497	197.1341	183	113	158	0.064485
Al	10.12467	187.9636	169	101	155	0.098552
A2	17.42986	199.6707	187	104	152	0.127692
A3	12.77873	195.0899	196	100	144	0.047996
A4	14.97288	192.8903	191	104	151	0.055302
<b>A</b> 5	22.19029	200.5918	174	118	148	0.055901
A6	16.69924	196.4523	178	103	143	0.051546
<b>A</b> 7	16.03994	196.0399	173	116	143	0.063667
A8	17.70043	199.277	189	125	140	0.089334
A9	22.61986	199.5751	179	128	153	0.060019

Participants	Pelvic Tilt 01 (deg)	Thigh Alignment 03 (deg)	One-Joint Hip Flexor Length 04 (deg)	Two-Joint Hip Flexor Length 06 (deg)	Hip Extensor Length θ7 (deg)	Center of Pressure (m)
A10	14.55357	194.5536	183	126	161	0.066012
A11	18.78862	198.5305	185	117	165	0.066757
A12	18.97041	197.9609	187	119	153	0.076195
A13	22.91283	199.0622	191	110	145	0.049176
A14	15.64225	194.2783	178	120	157	0.06786
A15	15.00492	199.6342	183	90	146	0.037617
A16	18.08345	197.5916	182	110	159	0.106886
A17	15.12401	195.4514	171	120	164	0.048918
A18	14.77455	193.9152	179	111	170	0.049752
C – Mean	16.90189	196.3533	185.0952	108	153.619	0.056487
C – SD	5.058925	6.507301	6.905829	9.348797	9.635747	0.015401
A – Mean	16.9117	196.5849	181.9444	112.3333	152.7222	0.067732
A – SD	3.367365	3.183399	7.487026	10.40362	8.628309	0.023727
TP – Mean	16.90641	196.4602	183.641	110	153.2051	0.061677
TP – SD	4.306118	5.180168	7.260155	9.960448	9.076225	0.020223

C = Caucasian

A = Eastern Asian

TP = Total Population

SD = Standard Deviation

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