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Effects of Power Generation and Two Different Landing Protocols on Evaluating Impact Attenuation in Landing

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To the Graduate Council:

I am submitting herewith a dissertation written by Kurt Gavin Clowers entitled "Effects of Power Generation and Two Different Landing Protocols on Evaluating Impact Attenuation in Landing." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Songning Zhang, Major Professor

We have read this dissertation and recommend its acceptance:

Edward T. Howley, Wendell P. Liemohn, Mehran Kasra

Accepted for the Council:

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Vice Chancellor and Dean of
Graduate Studies

EFFECTS OF POWER GENERATION AND TWO DIFFERENT LANDING PROTOCOLS ON EVALUATING IMPACT ATTENUATION IN LANDING

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee

Kurt Gavin Clowers
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Dedication

This dissertation is dedicated to my wife Cheryl Clowers who provided unyielding support and strength.

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To pronounce that this dissertation is by "Kurt Clowers" is an overstatement, without the contributions of many people this could not happen. There are many individuals who I would like to express my gratitude to for their support and help.

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Abstract

The purposes of the dissertation were: 1) to examine the effects of power generation and two different landing protocols on the lower extremity during a landing activity, and 2) to examine the effects of power generation and gender on impact attenuation during a landing activity.

During the first study, eight elite male recreational athletes and eight non-elite male recreational athletes, selected based upon their maximum jump heights, preformed drop landings in one of six conditions for two different protocols. Each subject landed from a height of 40 cm, 60 cm and 80 cm in the first protocol (PT1) and from a height of 70%, 100%, and 130% of their maximum vertical jump height in the second protocol (PT2). Ground reaction force (GRF) data were recorded using a force plate (OR6-7, AMTI) and kinematic data were recorded using a six camera motion analysis system (Vicon). Both the GRF and kinetic variables were normalized by potential energy. A Group × Protocol × Height mixed design repeated measures ANOVA with Group as the between subject factor was used to test the significance of selected variables. The non-elite athletes landed with a larger loading rate for the second GRF peak and a larger hip extension moment compared to the elite athletes. The non-elite athletes also landed with a greater ankle plantarflexion moment, knee adduction moment and ankle eccentric work in PT1 whereas the elite athletes landed with a smaller ankle plantarflexion moment, knee adduction moment and ankle eccentric work. These findings suggest that the elite athletes ware better equipped to absorb the loads at impact and that the two groups of athletes responded differently.

During the second study, additional sixteen female subjects divided into the non-elite and elite groups preformed drop landings in the same protocols as described in the first study. A Group × Gender ×Protocol × Height mixed design repeated measures ANOVA with Group and Gender as the between subject factors was used to test the significance of selected variables. No significant differences between the genders were observed. The elite group proved to land with smaller second GRF peak, greater ankle plantarflexion and knee extension moments compared to the non-elite group in PT1. These results demonstrated that the non-elite and elite athletes used different joint kinetic patterns to dissipate impact loading. Despite no statistical evidence supporting gender differences, females landed with a trend of greater percent increases in the first GRF peak while males landed with a trend of smaller second GRF peak. The elite males showed a decrease in the ankle eccentric work in PT1compare to PT2. The females showed no change in the ankle eccentric work across the two protocols. These findings demonstrated that the males and females might have used different neuromuscular control of the lower extremity joints to attenuate the forces at impact.

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Part I

Introduction

Many sporting activities involve landing, jumping, cutting movements, or a combination of all three. The jumping movement can be divided into an airborne phase and a landing phase. It is during the landing phase when the potential for injury increases. Investigators have found that the majority of injuries occur during landing and most often at the knee joint [1, 2]. It has been reported that season-ending knee injuries occur at a rate of 1 in 1000 in intercollegiate athletes each year [3]. Female athletes suffer more knee injuries when compared to males participating in the same sport [4, 5]. Studies conducted on the incidence rate of knee injuries in females show a four to six times incidence higher than their male counterparts [1-3, 5]. The medical cost of knee injuries has been estimated to be $119 million dollars annually for female high school basketball players alone [3]. Thus, it is necessary to examine injury mechanisms associated with the landing phase of activities.

Athletic skills such as rebounding in basketball or spiking in volleyball require tremendous jumping ability and a subsequent safe landing. The success of the jump is dependent on muscular power. Muscular power can be described as the ability of a muscle group to contract forcefully with speed [6] and can be quantified as the product of the force applied times the speed with which the force is applied.

A vertical jump is accomplished through a sequential application of musculotendinous power from the hip proximally to the ankle distally [6]. Thus, an increase in the speed of the muscle contraction, muscular strength, or a combination of both increases the height of the jump. Kreighbaum et al. [6] asserted that muscular power includes two mechanical properties of muscle, namely, the ability to generate large forces in a short period of time and the continuous production of that force as the velocity of muscle shortening increases. These mechanical properties of power can be improved through training. The first ability requires training which would improve the rate at which the muscles can apply their forces. The second property mandates specificity of training which requires the athlete/performer to train for strength gains at the velocity which is specific to the activity [6].

Investigators have conducted training studies on improving the two mechanical properties of power. One of the most common and acceptable activities used to measure the power output of a person is the maximum countermovement vertical jump [7]. Investigators implement training programs to improve vertical jump performance to asses the effects on the power output. The training programs vary greatly in terms of techniques and training methods, from training with heavier loads [8, 9] to plyometrics [10, 11].

Because of the increased potential for injury in landing related activities and the importance of muscular power in these sports, the biomechanical characteristics of landing have received a great deal of attention in biomechanics research. Research involving male subjects have focused on impact forces and comparisons or manipulation of landing heights and techniques [12-16]. Several studies have demonstrated that the magnitude of the lower extremity joint angles, moments, and GRF increases with increases in height [12, 14-16]. Likewise, changes in landing technique also influence the lower extremity joint angles, moments and GRF [12-16]. However, studies describing the biomechanical characteristics of the lower extremity during landing in females are not as abundant. Arampatzis et al. [17] demonstrated that landing techniques influence maximal impact peaks in female gymnasts. Hass et al. [18] showed that postpubescent women land with the knee more extended and have greater extensor moments at the hip and knee when compared to prepubescent girls.

Since the injury rate in females is greater than males when participating in sports that involve landing activities, a large number of studies have compared genders to determine why females are at greater risk. Chappell et al. [19] showed that female recreational basketball, volleyball, and soccer players land with greater peak proximal tibia anterior shear forces compared to matched recreational male athletes. Researchers have shown that there is no significant difference in GRF when comparing recreational female athletes to recreational males athletes in landing from 60 cm [20] and Division I female volleyball, basketball, and soccer athletes to matched male recreational athletes [21]. However, one study has shown that trained females have lower peak landing forces when compared to untrained males [22]. Comparisons of the lower extremity kinematics between genders have also been investigated to explore why females are at greater risk than males. Decker et al. [20] reported that female and male recreational athletes exhibit similar maximum knee flexion angles when landing from a height of 60 cm. Conversely, two studies involving male recreational athletes compared to female recreational athletes [23] and female Division I volleyball, basketball, and soccer athletes compared to matched male recreational athletes [21] demonstrated that females have significantly greater knee extension angles at contact. Fagenbaum et al. [24] reported that female Division I basketball players have significantly larger knee flexion angles at contact compared to male Division I basketball players. It was also reported that female high school basketball players have a greater total valgus knee motion when landing compared to male high school basketball players [25]. Research has shown that there are differences between genders in landing activities. However, there is a discrepancy in the results of different studies when examining the knee flexion angle at contact. Additionally, the inconstancy in the results describing knee flexion at contact may be due to the comparisons made. Therefore, further research characterizing gender differences during landing activities is warranted.

Few studies have compared the biomechanical characteristics of the lower extremities during landing in subjects with different experience or training levels. Hoffman et al. [26] reported that there was a correlation between leg strength and GRF in experienced parachutists compared to non-experienced parachutists. It was also demonstrated that individuals who train for power have decreased stiffness when landing [27]. Thus it would seem logical to assume that there would be differences in impact attenuation with different conditioning backgrounds and maximum power generation capabilities.

There is an additional confounder in investigating impact attenuation in landing activities. Two different landing protocols are often used when studying the biomechanical characteristics of landing. One protocol requires the subject to perform drop landings at predetermined heights [12, 14-16]. Another protocol requires the subject to perform the same type of landing from heights based on predetermined percents of his/her maximum vertical jump (MVJ) [13, 28, 29]. However, no one has examined the effects of the different protocols on impact related biomechanical variables and which protocol is better suited for impact attenuation investigation.

Problem Statement

The purpose of the study was three fold. One purpose was to investigate effects that power generation capacity has on impact attenuation in landing activities, with the participating subjects divided into recreational athletes who participated mostly in sports that require jumping/landing and have greater lower extremity power (elite), and recreational athletes who participate in sports that do not require jumping/landing (non-elite). The second purpose of this study was to compare the differences between the two landing protocols with the first landing-height protocol based on absolute heights and the second protocol based on the subject's MVJ to determine which protocol is better suited for studies on impact attenuation during landing activities. The final purpose was to compare differences between the two genders in the effects of conditioning/power generation capacity and the landing protocols on impact attenuation during landing.

Hypotheses

The following hypotheses were tested:

1) The non-elite group would demonstrate significantly less impact attenuation capabilities during landing compared to the elite group.

2) Females would demonstrate less ability to attenuate impact forces from landing when compared to males.

3) The non-elite group would demonstrate less ability to absorb impact forces when landing from the protocol based on absolute heights compared to the protocol based on MVJ.

Delimitations

The study was conducted within the following delimitations:

1) Sixteen male and sixteen female active and healthy recreational athletes were selected from the student population at The University of Tennessee. They had no impairments of the lower extremities at the time of testing.

2) Each subject performed six test conditions, which included drop landings from an overhead drop bar set at predetermined heights that were measured from the calcaneus to the landing surface.

3) Biomechanical signals were collected and analyzed for duration of 600 ms from touchdown.

4) Data were collected at 1080 Hz from a force platform, one electrogoniometer, and at 120 Hz from a motion analysis system for each trial of the landing activity.

Limitations

The study was limited by the following factors:

1) Subjects were limited to those drawn from the student population at The University of Tennessee.

2) Possible errors from placement and digitizing of the reflective markers. Other errors such as marker placement are acknowledged. Minimization of these errors is accomplished by understanding accurate anatomical information and repeated practice of marker placement. Furthermore, the use of an automatic digitizing program, such as Vicon, helped limit possible errors caused by the digitization of reflective markers.

3) Inherent errors in this study came from the force platform, electrogoniometer, and/or digital video systems. Errors of force platform and high-speed video systems are always present, but small and considered acceptable within the specifications of the manufacturers. The mean residuals from the calibration of the Vicon system for the male and female subjects were 0.890±0.109 mm and 0.953±0.050 mm respectively. Individual mean residual from calibrations for males and females can be found in Appendix C.

4) Another potential source of error is the movement of the reflective markers used to identify anatomical landmarks and body segments due to the task preformed. This was minimized by attaching non-collinear tracking markers to a rigid shell, which has proven to be optimal for reducing movement artifact [30, 31].

5) The accuracy of joint center estimation was limited by understanding accurate anatomical information, repeated practice of marker placement, and the careful placement of markers on medial and lateral bony landmarks. Estimation of the hip joint center could be another possible source of error. The hip joint center was estimated by using a modified method based upon markers placed on palpable bony landmarks of the pelvis and femur [32].

Assumptions

The following assumptions were made for this study:

1) Biomechanical measurements used were sufficient for analyzing effects of drop landings from different heights.

2) Biomechanical instruments used were accurate.

3) All subjects were free of injuries to the lower extremity at the time of testing.

4) The performance of the subjects was symmetrical, so only the right side was assessed for the kinematics and GRF.

References

1. Ferretti, A., et al., *Knee ligament injuries in volleyball players.* Am J Sports Med, 1992. **20**(2): p. 203-7.
2. Gray, J., et al., *A survey of injuries to the anterior cruciate ligament of the knee in female basketball players.* Int J Sports Med, 1985. **6**(6): p. 314-6.
3. Hewett, T.E., et al., *The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study.* Am J Sports Med, 1999. **27**(6): p. 699-706.
4. Arendt, E. and R. Dick, *Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature.* Am J Sports Med, 1995. **23**(6): p. 694-701.
5. Huston, L.J. and E.M. Wojtys, *Neuromuscular performance characteristics in elite female athletes.* Am J Sports Med, 1996. **24**(4): p. 427-36.
6. Kreighbaum, E. and K.M. Barthels, *Performance Analysis of Pushlike Movements*, in *Biomechanics: A Qualitative Approach for Studying Human Movement.* 1996, Allyn and Bacon: Boston. p. 619.
7. Dowling, J.J. and L. Vamos, *Identification of Kinetic and Temporal Factors Related to Vertical Jump Performance.* Journal of Applied Biomechanics, 1993. **9**(2): p. 95-110.
8. McBride, J.M., et al., *The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed.* J Strength Cond Res, 2002. **16**(1): p. 75-82.
9. Stone, M.H., et al., *Power and maximum strength relationships during performance of dynamic and static weighted jumps.* J Strength Cond Res, 2003. **17**(1): p. 140-7.
10. Fatouros, I.G.J., A.Z.; Leontsini, D.; and K.A. Taxildaris, N.; Kostopoulos, N.; Buckenmeyer, P., *Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength.* Journal of strength and conditioning research, 2000. **14**(4): p. 470-476.
11. Luebbers, P.E., et al., *Effects of plyometric training and recovery on vertical jump performance and anaerobic power.* J Strength Cond Res, 2003. **17**(4): p. 704-9.
12. Dufek, J.S. and B.T. Bates, *The evaluation and prediction of impact forces during landings.* Med Sci Sports Exerc, 1990. **22**(3): p. 370-7.
13. Gross, T.S. and R.C. Nelson, *The shock attenuation role of the ankle during landing from a vertical jump.* Med Sci Sports Exerc, 1988. **20**(5): p. 506-14.
14. McNitt-Gray, J.L., *Kinetics of the lower extremities during drop landings from three heights.* J Biomech, 1993. **26**(9): p. 1037-46.
15. Self, B.P. and D. Paine, *Ankle Biomechanics During Four Landing Techniques.* Medicine & Science in Sports & Exercise, 2001. **33**(8): p. 1338-1344.
16. Zhang, S.-N., B.T. Bates, and J.S. Dufek, *Contributions of Lower Extremity Joints to Energy Dissipation During Landings.* Medicine and Science in Sports and Exercise, 2000. **32**(4): p. 812-819.

17. Arampatzis, A., G.P. Bruggemann, and G.M. Klapsing, *A three-dimensional shank-foot model to determine the foot motion during landings.* Med Sci Sports Exerc, 2002. **34**(1): p. 130-8.
18. Hass, C.J., et al., *Lower Extremity Biomechanics Differ in Prepubescent and Postpubescent Female Athletes During Stride Jump Landings.* Journal of Applied Biomechanics, 2003. **19**: p. 139-152.
19. Chappell, J.D., et al., *A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks.* Am J Sports Med, 2002. **30**(2): p. 261-7.
20. Decker, M.J., et al., *Gender differences in lower extremity kinematics, kinetics and energy absorption during landing.* Clin Biomech (Bristol, Avon), 2003. **18**(7): p. 662-9.
21. Lephart, S.M., et al., *Gender differences in strength and lower extremity kinematics during landing.* Clin Orthop, 2002(401): p. 162-9.
22. Hewett, T.E., et al., *Plyometric Training in Female Athletes Decreased Impact Forces and Increased Hamstring Torques.* The American Journal of Sports Medicine, 1996. **24**(6): p. 765-773.
23. Huston, L.J., et al., *Gender differences in knee angle when landing from a drop-jump.* Am J Knee Surg, 2001. **14**(4): p. 215-9; discussion 219-20.
24. Fagenbaum, R. and W.G. Darling, *Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury.* Am J Sports Med, 2003. **31**(2): p. 233-40.
25. Ford, K.R., G.D. Myer, and T.E. Hewett, *Valgus knee motion during landing in high school female and male basketball players.* Med Sci Sports Exerc, 2003. **35**(10): p. 1745-50.
26. Hoffman, J.R., D. Liebermann, and A. Gusis, *Relationship of leg strength and power to ground reaction forces in both experienced and novice jump trained personnel.* Aviat Space Environ Med, 1997. **68**(8): p. 710-4.
27. Hunter, J.P. and R.N. Marshall, *Effects of power and flexibility training on vertical jump technique.* Med Sci Sports Exerc, 2002. **34**(3): p. 478-86.
28. James, C.R., J.S. Dufek, and B.T. Bates, *Effects of injury proneness and task difficulty on joint kinetic variability.* Med Sci Sports Exerc, 2000. **32**(11): p. 1833-44.
29. Ross, S.E. and K.M. Guskiewicz, *Examination of Static and Dynamic Postural Stability in Individuals With Functionally Stable and Unstable Ankles.* Clin J Sport Med, 2004. **14**(6): p. 332-338.
30. Manal, K., et al., *Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study.* Gait Posture, 2000. **11**(1): p. 38-45.
31. McClay, I. and K. Manal, *Three-dimensional kinetic analysis of running: significance of secondary planes of motion.* Med Sci Sports Exerc, 1999. **31**(11): p. 1629-37.
32. Seidel, G.K., et al., *Hip joint center location from palpable bony landmarks--a cadaver study.* J Biomech, 1995. **28**(8): p. 995-8.

Part II

Literature Review

The purpose of this study was to investigate the effect that power generation capacity has on impact attenuation in landing activities in addition to comparing the differences between two landing protocols in relation to gender to understand which protocol is better suited for studies on impact attenuation during landing activities and differences between genders. The objective of this literature review is to present findings exploring the relationship between power generation capacity and impact attenuation. Further research is reviewed on landing specifically, the biomechanical characteristics of landing for males and females, and gender differences in landing, participation/experience level, and protocol differences. Other studies related to marker sets and hip joint center estimation are also reviewed.

Power Generation

Many different sports and athletic skills require the athlete/performer to generate tremendous amounts of muscular power. Muscle power can be noted as the ability of a muscle to contract forcefully with speed. Since power is equal to the amount of an applied force multiplied by the speed at which the force is applied, an increase in strength (i.e. muscle torque) or an increase in the speed of muscle contraction produces greater power.

In order to generate maximum power one must produce a maximum force to accelerate a resistance in the shortest period of time. Examples of maximum force activities used for increasing maximum power, often called power lifting, are the bench press, the squat, and the deadlift. However, in these events the velocity of the lift is very low and thus, contributes little to performance because the lift is associated with force production throughout a range of motion [6]. In contrast, Olympic lifts such as the snatch and the clean-and-jerk are examples that incorporate and develop power to a great extent [6].

Garhammer [33] calculated the mechanical power output produced in the body for the bench press, the snatch, and the clean and jerk. He discovered that the bench press had the lowest power output and that the snatch and the clean-and-jerk had the highest power output. Both lifts required higher power output because they involve the whole body and must be executed rapidly [33]. A successful snatch, or clean-and-jerk, requires that the athlete/performer train for strength gains at a velocity specific to the activity; this is known as specificity of training [6, 34]. This type of training is used to improve the mechanical properties of muscle, namely the ability to generate large forces in a short period of time and the continuous production of that force as the velocity of muscle shortening increases [6].

Therefore, investigators seeking the best way to improve muscular power have concentrated their efforts on studying specific training regimes. Training with heavy loads have been shown to increase the vertical jump performance of athletes [8, 9]. Specifically, improvements in peak force, peak power, and one repetition maximums (1RM) were observed [8, 9]. However, training with heavy loads (e.g. 80% 1RM) can decrease horizontal performance (i.e. sprint times) of athletes [8]. Investigators have examined other methods for improving power output, especially plyometric training. Fatouros et al. [10] conducted a 12 week training program to determine the effects of plyometric training on selected jump performance variables. They discovered that a training program combining both plyometrics and a routine of lower body exercises (e.g.

squats, calf raises, leg press, leg curls and squat jumps) were better for improving jump performance/power output [10]. A combination of training with lighter loads and plyometrics is optimal for improving performance in the vertical plane while not diminishing performance in the horizontal plane.

Specificity of training is not the only aspect investigated when examining improvements in power generation capacity. Physical activity has been shown to be an important component of muscular power generation [35]. The peak instantaneous power of sedentary males and females was compared to that of volleyball players and weight lifters. The peak power for both sedentary males and females was significantly higher when they performed a vertical jump with no external loads compared to jumps with external loads of 5 kg and 10 kg. Conversely, for the volleyball players and weight lifters there were no significant differences in the peak power with or without loading. Thus, these results suggest that physical conditioning plays an important role in power generation.

Muscular power generation is crucial in many sports and athletic skills. Investigators have focused their attention on improving one or both of the mechanical properties of muscle to increase power generation. Training to improve power generation leads to improvements in vertical jump height. However, the physical conditioning of the performer is dependent on the amount of power output.

Vertical Jump

The most common method for examining power output in humans is the maximum vertical jump (MVJ) [7]. A vertical jump mandates that a jumper apply a ground reaction force (GRF) to the body's mass while the body is still in contact with the ground in order to accelerate the body as much as possible [6]. The jumper creates a greater GRF by a sequential application of musculotendinous power from the hip proximally through the ankle distally [6]. Thus, the magnitude of force application and the speed at which the force is applied are important to the height of the jump.

Dowling et al. [7] used the vertical GRF force-time curve of the vertical jump to identify kinetic and temporal characteristics related to jump performance. Mechanical power was calculated for each subject by multiplying the vertical ground reaction force by the vertical velocity of the subject's center of mass. Dowling found that among the 18 independent variables initially investigated six were significantly related to the jump height. These variables included: peak GRF, time between maximum force and takeoff, maximum negative power, maximum positive power, time between maximum power and takeoff, and ratio of negative to positive impulse. The best single predictor for jump height was maximum power because of its high positive correlation with the jump height ($r = .928$).

A jumper uses muscular power to generate momentum to project his/her center of mass upward. It is during the landing phase when the potential for injury and overuse injuries [36].

Landing

The majority of injuries occur during landing from a jump and the most severely injured joint is the knee [1, 2]. Therefore, many researchers have documented the performance characteristics of landing activities to evaluate injury mechanisms. The studies of landing biomechanics have focused on various aspects of the activity; including biomechanical characteristics of landing, performance characteristics, and differences of landing for males and females, and effects of participation/training level (e.g. elite vs. recreational); and the physical activity level or experience level on landing and jumping biomechanics. Additionally, studies investigating landing biomechanics often employ two different landing protocols: one that requires subjects to land from absolute heights and another in which landing heights are determined based on a percentage of the subject's MVJ.

Performance Characteristics

Biomechanical Characteristics. The performance characteristics for landing in males have been widely investigated. Researchers have evaluated the effects of height, distance, and landing technique on impact forces during landings. Most individuals demonstrate two distinctive peaks of maximum vertical ground reaction force (GRF) with the first peak (F1) related to the toe contact and the second peak (F2) related to the heel contact [16]. However, an interesting finding is that not all males exhibit the toe-heel landing peaks normally observed; some employ individual strategies [12]. The magnitude of the peak GRF has been shown to be dependent on landing height [12, 14, 16]. Not only does height influence the magnitude of peak GRF, but the landing technique can be influential. The smaller the maximum knee flexion angle for a person performing a landing the greater the magnitude observed for the peak GRF [15, 16]. These particular findings reveal that there is increased loading on the body with increases in either landing height or landing stiffness.

Similarly, the kinetics of the lower extremity joints during landing for males has also been described. During the landing phase the sagittal joint kinetics show eccentric muscle contractions with a net ankle plantarflexor moment and the net hip and knee extensor moments [14]. Studies have revealed that the peak extensor joint moments increase in magnitude when encountering progressively higher impact velocities [14, 16]. Furthermore, peak knee extensor moments have been shown to be less than the peak magnitudes for the ankle and hip extensor moments when landing [14]. Similarly, the work done by the extensor muscles of the ankle, knee, and hip significantly increase as the velocity of impact increases [14, 16]. Changes in the eccentric work pattern from low to high heights for the hip and ankle joint muscles in different landing techniques have also been documented. As landing heights increase the eccentric work of the hip, knee, and ankle joints increase [16]. However, the ankle plantarflexors have been shown to increase eccentric work with increased stiffness while the knee and hip extensors decrease eccentric work with increased stiffness [16].

Gender Differences

Previous studies have been performed to examine differences between males and females [19-25]. One of the more commonly injured joints in females, when compared to males, is the knee [4, 25]. Because the knee and especially knee ligamentous injuries occur more frequently in female athletes than male, investigators have compared the differences between genders to study this disparity. The reviews of these studies are categorized into kinematics, GRF, and joint kinetics.

Kinematics. Kinematic differences for genders are well documented. When comparing knee flexion angles from landing between genders most research suggests that females have greater knee extension (i.e. less flexion) at contact [21, 23, 24]. One study reported that male recreational athletes landed with significantly larger knee flexion angles at touchdown when landing from heights of 40 cm and 60 cm compared to female recreational athletes [23]. A similar study reported that female Division I basketball, volleyball, and soccer players had significantly less knee flexion at contact and the time to maximum knee flexion compared to matched recreational male athletes [21]. However, one study documented that female Division I basketball players had significantly greater knee flexion angles at contact when compared to male Division I basketball players landing from a height of 50.8 cm [24].

Studies conducted on females alone have established that post-pubescent women land with their knee more extended and their hip more flexed when compared to prepubescent girls [18]. A study conducted on female gymnasts demonstrated that they exhibit small maximal dorsiflexion angles when landing from 80 cm compared to 115 cm [17]. No statistical differences were found for the maximal eversion-inversion or abduction-adduction at the tibiotalar joint but with high variability, similar to what has been observed in running [17]. Additionally, it has been shown that prepubescent girls land with 4.5^0 greater knee flexion when compared to post-pubescent women [37].

The comparison of other kinematic variables between males and females has also been conducted with less disparity in the results. Decker et al. [20] reported that both male and female recreational athletes had similar maximum knee flexion angles when landing from 60 cm. No significant differences have been discovered in the knee range of motion between female and male recreational athletes when landing from heights of 20, 40, and 60 cm [23]. However, Division I female athletes compared to matched male recreational athletes exhibit greater hip internal rotation and smaller leg internal rotation [21]. In addition, significantly higher knee valgus motion was observed in female high school basketball players when compared to their male counterparts [25].

GRF. A study demonstrated that female gymnasts had significantly larger forefoot and rearfoot peak GRF forces when landing with a hard landing technique compared to a soft landing technique [17]. Hass et al. reported that prepubescent girls have significantly longer time to peak GRF [18] and greater peak toe contact forces [37] when compared to post-pubescent women. However, no significant differences were observed in GRF variables between male recreational athletes and female Division I basketball players at a landing height of 20 cm [21]. Another study reported no significant differences in GRF variables between male and female recreational athletes when landing from a height of 60 cm [20]. Comparison of male and female recreational athletes has shown that women have significantly larger peak proximal tibia anterior shear force during landing [19]. However, after participating in a jump training program women exhibited significantly lower peak GRF forces than untrained males [22].

Kinetics. The final category of the review on gender differences is landing kinetics. Landing from a height of 60 cm, female and male recreational athletes demonstrated no significant differences for peak lower extremity joint moments, powers and work [24]. However the peak knee extensor moment occurred much sooner for males than females. The peak hip extensor moment was significantly greater than the ankle plantar flexor moment for females and in males the peak hip extensor moment was significantly larger than the peak knee extensor and ankle plantar flexor moments [24]. It was also reported that the peak negative hip extensor power was greater than the peak negative ankle and knee extensor powers for the males, while the females demonstrated no significant differences between peak negative powers of the lower extremity [24]. The females demonstrated greater energy absorption from the knee and ankle compared to the hip, whereas no significant differences were reported for the males. Also, the females had higher total energy absorption compared to males. On the other hand it has been reported that the peak torque for the lower extremity joints after landing from a 20 cm platform was significantly lower in Division I female athletes when compared to male recreational athletes [21]. Females who participated in a jump training program had significantly lower peak knee adduction/abduction and knee extension moments during landing when compared to untrained males [22].

Prepubescent females exhibited significantly greater knee extensor moments during lateral, vertical and static landings compared to post-pubescent women [37]. For the same activities post-pubescent women demonstrated significantly larger peak knee mediolateral and anteroposterior forces than prepubescent women [18]. When examining vertical landings only, prepubescent girls have been shown to generate less knee internal/external rotation power compared to post-pubescent women [18].

There is a large body of literature documenting the differences between genders in the kinematics, GRF, and joint kinetics for landing. Some discrepancy still exists in the knee flexion angle at contact when comparing genders. Specifically, when comparing the same level of participation or experience level in landing recreational female and male athletes have similar knee flexion angles. However, the knee flexion angle was reportedly greater in Division I female basketball athletes compared to males with the same experience and training [24].

Participation/Experience Level

Effects of participation/experience level (e.g. elite or recreational athletes) have received limited attention in research. The motivation behind examining differences in participation level varies. Hoffman et al. [26] investigated if power generation influence the parachute landing process of parachute jumpers. The authors used the one repetition maximum squat as a measure of power output. They then asked experienced and novice parachutists to land from three different heights. Additionally, they calculated maximal power as the product of the mean vertical force and velocity of 15 counter movement jumps (CMJ) for each subject. They found no significant differences in maximum power between experienced and non-experienced parachutists. However, when the data were collapsed across heights, a significant group effect was observed in the second peak GRF even though there were no significant interactions between groups and heights. There was a positive correlation between maximal power and the GRF in experienced jumpers but not in the novice jumpers. Hunter et al. [27] investigated the effects of power training and stretching on both countermovement jumps and drop jumps. Stiffness was calculated from the ratio of change in GRF to the change in the height of the subject's center of mass that was used to determine the effectiveness of the training program. After landing from heights of 30 cm, 60 cm, and 90 cm, the power training group and the power training and stretching group demonstrated decreased stiffness for the drop jumps. The stretching only group showed no significant differences. The effects of the participation or experience level on landing biomechanics is not as well documented, especially on impact attenuation during landing. The limited body of literature warrants further study on differences between experienced performers and those who are less experienced in impact related variables during landing activities.

Protocol Differences

Traditionally studies in landing biomechanics employ two types of landing protocols when determining the height from which the subject lands. One of the protocols is based on absolute heights while the other is based on a percentage of the subject's MVJ. The results from studies that employ a protocol based on absolute heights have been reported in the previous sections above. Several studies using the landing protocol based on MVJ heights are reviewed.

Gross et al. [13] investigated the role of the ankle in the shock attenuation process during barefoot landings from a vertical jump. The protocol required subjects to perform a CMJ and touch a bar set at a height of 90% of their MVJ in order to equalize efforts across all subjects and produce landing symmetry. All subjects demonstrated the typical two GRF peaks associated with landing and all subjects were noted as having the ankle dorsiflexed prior to ground contact. In another landing study that used percentages of the subjects' MVJ, 10 male and 10 female recreational athletes were placed into either a healthy group or an injury prone group [28]. After which, they were instructed to land from 50%, 100%, and 200% of their MVJ. Statistical analysis revealed that the peak joint moment variables for the 100% MVJ height tended to have greater variability than for the 50% MVJ height in both groups. The results for the time to peak joint moment variables demonstrated greater variability at the 100% MVJ height than either the 50% or 200% MVJ heights for both groups. Hass et al. [37] also used a protocol based on subject's MVJ to compare knee biomechanics during landings of pre- and postpubescent females. Each subject was required to land from a height that matched their individual MVJ. The results indicated that postpubescent females exhibited reduced knee flexion at contact, increased mediolateral knee joint forces, and less knee extensor moments compared to prepubescent girls.

Regardless of the protocol employed in landing studies, the variation due to individual differences in landing height, body weight and body height must be minimized before a comparison of the dependent variables can be made. This minimization is accomplished through a process known as normalization. Studies that use a protocol based on absolute heights often normalize the dependent variables by one of several schemes. One method involves normalization of GRF and joint moment variables by multiples of body weight (BW) and body mass respectively [12, 14, 17, 18]. Other investigators normalize both GRF and moments by body mass [16] or by BW × body height [19]. Still another method involves normalizing the GRF by BW and the joint moment variables by BW × body height [20]. Since the subjects are landing from the same height in the protocol based on absolute heights, the normalization scheme used must account for the differences in body mass between subjects. Hence, the methods described above are all suitable for accounting for the differences.

However, there is a confounding problem when a protocol based on percentages of MVJ is used in landing studies in that all subjects are landing from different heights. Therefore investigators must account for the different landing heights in addition to individual body masses. Gross et al. [13] who investigated impact attenuation of subjects landing from 90% of their MVJ reported the GRF results in multiples of BW. Another study which had subjects land from 50%, 100%, and 200% of their MVJ normalized all joint moment variables to body mass [28]. These two studies' methods of normalization are insufficient in minimizing the variation due to landing height. Conversely, a third study by Hass et al. [37] described the knee biomechanics of pre and post pubescent females for which the protocol required the subjects to land from a height matched to their MVJ. The peak joint moments were normalized to mass × body height × √ landing height and the GRF were normalized to body mass × √ landing height. The rational provided for choosing this scheme was that the GRF during the landing phase is proportional to the square root of landing height based on the impulse-momentum relationship and the properties of uniformly accelerated motion [37]. While this normalization scheme relates the different landing heights of each subject, the purpose of taking the square root of the landing height may be to diminish the effect the denominator has on the numerator instead of just using landing height. However, perhaps a better method still is to normalize the dependent variable by potential energy. Zhang et al. [38] showed that traditional normalization methods yielded statistically insignificant differences in selected GRF variables but normalization by potential energy proved effective in demonstrating statistical differences in GRF variables in two types of shoes during jumping activities. Potential energy is the energy due to gravity which increases as the height of the body above ground increases. Therefore, a potential energy normalization scheme may be useful in detecting differences not otherwise seen due to the differences in jump heights achieved by subjects.

Due to the fact that the majority of injuries occur during landing from a jump, a large body of literature has developed for the biomechanical characteristics of landing activities. The studies have investigated biomechanical characteristics of landing, differences between genders, the effects of physical activity level or experience level on landing biomechanics, and the two different protocols for landing heights. The results of these studies have shown that there are differences in gender and experience level. However comparisons across genders, specifically the knee flexion angle, have yielded different results. These differences may be partly due to the methods used. In particular, one study compared Division I athletes to recreational males [24] and another study compared trained females to untrained males [22]. Also, additional confounders such as different protocols and normalization methods have been used to examine landing biomechanics. Because of the differences observed across genders and training levels in addition to differing protocols, further studies are warranted to examine the effects of experience levels and protocols in landing biomechanics.

Marker Sets and Joint Center Estimation

Marker Sets

The correct marker set (i.e. one that limits movement artifact) is crucial to the successful study of human movement activities. The invention of computer aided systems such as Vicon have revolutionized the field of three-dimensional (3D) biomechanics and allowed for quick and accurate measurements of 3D kinematic parameters of human movements through reflective surface markers placed on key anatomical sites. Therefore, an external marker system must be employed that can routinely and easily define the relative motion of a rigid body segments in three dimensions [39].

Kadaba et al. [39] developed a marker set, known as the Helen-Hayes marker set in which human body segments are modeled as rigid bodies and the relative rotation is assumed to take place about a fixed point in the proximal segment. The point where the relative rotation of a rigid body segment occurs is considered to be the joint center. The Helen-Hayes marker set uses markers placed on anatomical landmarks that help to minimize relative motion between skin and underlying bony structures.

A source of error in any movement analysis system is the estimation of the hip joint center. The Helen Hayes marker set has a deficiency in estimating joint centers, in particular, the hip. The Helen Hayes setup uses empirical equations to define the location of the hip joint center. However, these equations result in an offset of two degrees in all three directions from the true joint center [39]. Therefore, if the estimation of the hip joint center is inaccurate, any resulting joint angular or kinetic computations will reflect that inaccuracy. Additionally, the joint center is calculated using information from the proximal segment. Any mistake in the actual location of the proximal segment can cause errors to spread from one segment to another [30, 40, 41].

In any marker set, such as the Helen-Hayes, that uses individual tracking markers attached to a body segment which is separated from bone by soft tissue there are limitations. The individual tracking markers move independently of each other because of the soft tissue movements relative to the bone. Thus any subsequent calculation will contain errors. This movement of the marker has been shown to cause knee abduction/adduction and internal/external rotation to differ as much as 50 and 100%, respectively [30].

The limitations of the Helen-Hayes marker set led to the development of a marker set first introduced at the NIH biomechanics lab, which use a six degree of freedom approach to track the motion of each body segment independently [30, 40, 41]. The marker set use non-collinear reflective markers attached to a rigid and conformable shell placed on a body segment to track its movements. This helps to reduce errors because the markers all move relative to each other. Typically, four non-collinear markers are placed on the rigid structure which provides redundancy and helps compensate in the event a tracking marker is momentarily obscured [30, 40, 41]. The rigid structure/shell does not encumber the subject and the way that it is mounted helps to minimize soft-tissue vibrations and measurement errors observed in other marker sets [30, 40, 41].

Hip Joint Center Estimation

There are many different methods for defining the hip joint center. However, only a few are described here. One approach of estimating the hip joint center used in three-dimensional kinematics was proposed by Kadaba et al. [39]. They used a regression model based on a pelvic radiograph to estimate the location of the hip joint center relative to the anterior superior iliac spine (ASIS) locations. For this method, the X, Y, Z coordinate distances of the hip center from the ASIS marker are calculated as a function of the leg length [39].

Grood and Suntay [42] defined the joint center as an axis or point about which the two rigid bodies must rotate. First, the geometry of each body segment is created by using a Cartesian coordinate system and a set of surfaces to describe its shape. Next the angular position and the corresponding rotational motion between the two rigid bodies is specified by three independent angles. Three non-orthogonal unit vectors of the coordinate system are used to define the axes. Two of the axes, called fixed body axes, are embedded in the two rigid bodies whose relative motion is to be described. The third axis is called the floating point axis which is perpendicular to the body's fixed axes and its orientation is given by the cross product of the other two fixed body unit vectors. Two reference points located in each body are used to describe joint translations. A vector is used to characterize the relative position of the reference points and connects each body. Joint rotations are described relative to one another. That is, one body segment may be thought of as spinning about its own fixed axis while the other body segment remains stationary.

Another method of defining joint centers/hip joint center was described by Vaughn [43]. An orthogonal reference system is created and based on the three segmental markers. For the hip joint center, a marker is placed on the sacrum and it is considered the origin. Two additional markers indicate the right ASIS and the left ASIS respectively. These three markers form a plane, to which one axis is perpendicular to this plane, another axis is parallel to the line between the right and left ASIS, and the last axis is at a right angle to the other two so that the three axes form a right-handed system. Lastly, prediction equations along with collected anthropometric data are used to estimate the position of the left and right hip joint center.

The hip joint center can also be estimated from palpable bony landmarks. Sixty-five pelves were removed from cadavers and measured to create a method for estimating the hip joint center from palpable bony landmarks [32]. The pelvic measurements made included pelvic width (ASIS – ASIS), pelvic height (perpendicular from the pubic center to the inter-ASIS line), and pelvic depth (ASIS to the posterior superior iliac spine PSIS). Correlation analysis revealed that the successful estimation of the hip joint center is optimally located relative to 14% of pelvic width, 34% pelvic depth, and 79% of the pelvic height.

Many studies have been reviewed to provide support to the purpose of this study. The connection between power generation capacity and impact attenuation was established. The biomechanical characteristics of landing for males and females, gender differences in landing, participation/experience level, and protocol differences were also presented. Studies supporting the use of a particular marker set and estimation of hip joint center were also included in the review.

References

1. Kreighbaum, E. and K.M. Barthels, *Performance Analysis of Pushlike Movements*, in *Biomechanics: A Qualitative Approach for Studying Human Movement.* 1996, Allyn and Bacon: Boston. p. 619.
2. Garhammer, J., *Weight Lifting and Training*, in *Biomechanics of Sport*, C.L. Vaughan, Editor. 1989, CRC Press: Boca Raton. p. 169-212.
3. Baechle, T.R. and R.W. Earle, *The Biomechanics of Resistance Exercise*, in *Essentials of Strength Training and Conditioning.* 2000, Human Kinetics: Champaign, IL. p. 25-56.
4. McBride, J.M., et al., *The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed.* J Strength Cond Res, 2002. **16**(1): p. 75-82.
5. Stone, M.H., et al., *Power and maximum strength relationships during performance of dynamic and static weighted jumps.* J Strength Cond Res, 2003. **17**(1): p. 140-7.
6. Fatouros, I.G.J., A.Z.; Leontsini, D.; and K.A. Taxildaris, N.; Kostopoulos, N.; Buckenmeyer, P., *Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength.* Journal of strength and conditioning research, 2000. **14**(4): p. 470-476.
7. Driss, T., et al., *Effects of external loading on power output in a squat jump on a force platform: a comparison between strength and power athletes and sedentary individuals.* J Sports Sci, 2001. **19**(2): p. 99-105.
8. Dowling, J.J. and L. Vamos, *Identification of Kinetic and Temporal Factors Related to Vertical Jump Performance.* Journal of Applied Biomechanics, 1993. **9**(2): p. 95-110.
9. Radin, E.L. and I.L. Paul, *Response of joints to impact loading. I. In vitro wear.* Arthritis Rheum, 1971. **14**(3): p. 356-62.
10. Ferretti, A., et al., *Knee ligament injuries in volleyball players.* Am J Sports Med, 1992. **20**(2): p. 203-7.
11. Gray, J., et al., *A survey of injuries to the anterior cruciate ligament of the knee in female basketball players.* Int J Sports Med, 1985. **6**(6): p. 314-6.
12. Zhang, S., B.T. Bates, and J.S. Dufek, *Contributions of Lower Extremity Joints to Energy Dissipation During Landings.* Medicine and Science in Sports and Exercise, 2000. **32**(4): p. 812-819.
13. Dufek, J.S. and B.T. Bates, *The evaluation and prediction of impact forces during landings.* Med Sci Sports Exerc, 1990. **22**(3): p. 370-7.
14. McNitt-Gray, J.L., *Kinetics of the lower extremities during drop landings from three heights.* J Biomech, 1993. **26**(9): p. 1037-46.
15. Self, B.P. and D. Paine, *Ankle Biomechanics During Four Landing Techniques.* Medicine & Science in Sports & Exercise, 2001. **33**(8): p. 1338-1344.
16. Chappell, J.D., et al., *A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks.* Am J Sports Med, 2002. **30**(2): p. 261-7.

17. Decker, M.J., et al., *Gender differences in lower extremity kinematics, kinetics and energy absorption during landing.* Clin Biomech (Bristol, Avon), 2003. **18**(7): p. 662-9.
18. Fagenbaum, R. and W.G. Darling, *Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury.* Am J Sports Med, 2003. **31**(2): p. 233-40.
19. Ford, K.R., G.D. Myer, and T.E. Hewett, *Valgus knee motion during landing in high school female and male basketball players.* Med Sci Sports Exerc, 2003. **35**(10): p. 1745-50.
20. Hewett, T.E., et al., *Plyometric Training in Female Athletes Decreased Impact Forces and Increased Hamstring Torques.* The American Journal of Sports Medicine, 1996. **24**(6): p. 765-773.
21. Huston, L.J., et al., *Gender differences in knee angle when landing from a drop-jump.* Am J Knee Surg, 2001. **14**(4): p. 215-9; discussion 219-20.
22. Lephart, S.M., et al., *Gender differences in strength and lower extremity kinematics during landing.* Clin Orthop, 2002(401): p. 162-9.
23. Arendt, E. and R. Dick, *Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature.* Am J Sports Med, 1995. **23**(6): p. 694-701.
24. Hass, C.J., et al., *Lower Extremity Biomechanics Differ in Prepubescent and Postpubescent Female Athletes During Stride Jump Landings.* Journal of Applied Biomechanics, 2003. **19**: p. 139-152.
25. Arampatzis, A., G.P. Bruggemann, and G.M. Klapsing, *A three-dimensional shank-foot model to determine the foot motion during landings.* Med Sci Sports Exerc, 2002. **34**(1): p. 130-8.
26. Hass, C.J., et al., *Knee biomechanics during landings: comparison of pre- and postpubescent females.* Med Sci Sports Exerc, 2005. **37**(1): p. 100-7.
27. Hoffman, J.R., D. Liebermann, and A. Gusis, *Relationship of leg strength and power to ground reaction forces in both experienced and novice jump trained personnel.* Aviat Space Environ Med, 1997. **68**(8): p. 710-4.
28. Hunter, J.P. and R.N. Marshall, *Effects of power and flexibility training on vertical jump technique.* Med Sci Sports Exerc, 2002. **34**(3): p. 478-86.
29. Gross, T.S. and R.C. Nelson, *The shock attenuation role of the ankle during landing from a vertical jump.* Med Sci Sports Exerc, 1988. **20**(5): p. 506-14.
30. James, C.R., J.S. Dufek, and B.T. Bates, *Effects of injury proneness and task difficulty on joint kinetic variability.* Med Sci Sports Exerc, 2000. **32**(11): p. 1833-44.
31. Zhang, S., K. Clowers, and C. Kohstall, *Impact Attenuation and Kinetic Characteristics of Training Shoes in Landing and Jumping Activities*, in *2005 Annual Conference of American College of Sports Medicine*. 2005: Nashville, TN.
32. Kadaba, M.P., H.K. Ramakrishnan, and M.E. Wootten, *Measurement of Lower-Extremity Kinematics During Level Walking.* Journal of Orthopaedic Research, 1990. **8**(3): p. 383-392.

33. Karlsson, D. and R. Tranberg, *On skin movement artefact-resonant frequencies of skin markders attached to the leg.* Human Movement Science, 1999. **18**: p. 627-625.
34. Manal, K., et al., *Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study.* Gait Posture, 2000. **11**(1): p. 38-45.
35. Reinschmidt, C., et al., *Effect of skin movement on the analysis of skeletal knee joint motion during running.* J Biomech, 1997. **30**(7): p. 729-32.
36. Grood, E.S. and W.J. Suntay, *A joint coordinate system for the clinical description of three-dimensional motions: application to the knee.* J Biomech Eng, 1983. **105**(2): p. 136-44.
37. Vaughan, C.L., *Dynamics of Human Gait.* 2nd ed. 1999, Cape Town: Kiboho Publishers. 141.
38. Seidel, G.K., et al., *Hip joint center location from palpable bony landmarks--a cadaver study.* J Biomech, 1995. **28**(8): p. 995-8.

Part III

Effects of Power Generation on Lower Extremity Landing Biomechanics

Abstract

Few studies have investigated the effects of power generation capabilities on impact attenuation from landing. The purposes of this study were to investigate effects that power generation capacity has on impact attenuation in landing activities for elite (n = 8) and non-elite (n = 8) athletes and to compare the differences between two landing protocols. All subjects performed five landing trials from heights of 40, 60, and 80 cm in the first protocol (PT1) and from 70%, 100%, and 130% of their MVJ height in the second protocol (PT2). Ground reaction force (GRF, 1080 Hz) and three-dimensional kinematic data (120 Hz, six cameras) were recorded simultaneously and was used to calculate joint moments, powers, and work done on the three lower extremity joints. Results indicated a significantly larger peak GRF (F2, heel-strike) loading rate and hip extension moment for non-elite athletes. Significant interaction effects were observed for both groups of athletes for the ankle plantarflexion and knee adduction moments and ankle eccentric work in the protocol with the lowest heights for each group. The results suggest that elite athletes attenuate the impact forces during landing better and that the two groups of athletes respond differently to the two different protocols. *Key Words*: protocol differences, impact attenuation, lower extremity biomechanics

Introduction

Investigators have found that the majority of lower extremity injuries occur during landing and often at the knee joint [1, 2]. It has been reported that season ending knee injuries occur at a rate of 1 in 1000 intercollegiate athletes each year [3]. One of the more common methods that is often employed to investigate these potential injury mechanisms are landing studies.

Past research on landings has demonstrated that with increases in height the magnitude of the lower extremity joint angles, peak joint moments and vertical ground reaction forces (GRF) increase [12, 14-16] and changes in landing technique influence the lower extremity joint angles, moments, work, and GRF [12-16]. Few studies have examined the effects of power generation and/or training levels on the biomechanical characteristics of the lower extremity during landing. One study reported that there was a correlation between leg strength and the second maximum peak GRF in experienced parachutists compared to non-experienced parachutists [26]. Hunter demonstrated that individuals who train for power have decreased stiffness (ratio of change in GRF to change in height of subject's body mass center) upon landing [27]. Athletic skills such as rebounding in basketball or spiking in volleyball require a sequential application of musculotendious power in the lower extremity joints to successfully lift the body off the ground. The vertical jump is also a common method to measure an individual's power output [7]. Thus it seems logical to assume that there would be differences in impact attenuation in athletes with different conditioning backgrounds and maximum power generation capabilities.

An additional confounder in investigating impact attenuation in landing activities is that studies use one of two different landing protocols. One protocol requires the subject to perform drop landings at predetermined heights [12, 14-16]. The other requires the subject to perform the same type of landings from heights based on predetermined percents of his/her maximum vertical jump (MVJ) [13, 28]. No research has examined which protocol is better suited for impact attenuation investigation.

The purposes of this study were to investigate effects of power generation capacity on impact attenuation related biomechanical variables in landing activities, and to compare the differences between the two landing protocols to determine which protocol is better suited for studies on impact attenuation during landing activities. Two research hypotheses were tested: (1) athletes with less jumping/landing related experiences would demonstrate significantly less impact attenuation capabilities during landing compared to the athletes with different power generation capabilities and experience levels and (2) athletes with less jumping/landing related experiences and athletes with different power generation capabilities and experience levels would respond differently when landing from the protocol based on absolute heights compared to the protocol based on a percentage of the subject's maximum vertical jump (MVJ).

Methods

Subjects. Thirty-three healthy males were screened for inclusion for the study. A total of 16 subjects who met the following inclusion criteria were placed into one of two experimental groups: eight subjects (age: 22.25±1.49 years, mass: 86.43±12.29 kg, height: 1.85±0.06 m) who jumped 64 cm or higher and had self reported activities of either basketball, volleyball, or weightlifting three or more times a week were placed in the elite group and eight subjects (age: 24.00±2.83 years, mass: 78.34±8.18 kg, height: 1.82±0.04 m) who jumped 54 cm or less and did not participate in any jumping/landing movements regularly were placed in the non-elite group. The cut-off jump height for each group was determined from the jump heights and their self reported activities of the first 15 screened subjects. A mean MVJ for each subject was first computed and the cut-off heights were then determined to ensure 10 cm of separation between the two groups. All participating subjects were injury free at the time of testing and signed a written informed consent form approved by the Institution Review Board at The University of Tennessee.

Experimental Protocol. Each subject participated in two test sessions. During the first test session subjects performed a warm up followed by three MVJ with arm swing using a Vertec jumping board (Korney Board Aids, Inc., Roxton, TX). During the second test session each subject performed three-drop landings using a normal landing technique at the beginning of each height for each condition with an electrogoniometer (Biometrics Ltd UK) to determine an average maximum knee joint angle and provided an opportunity for the subject to familiarize themselves with each condition. The maximum knee joint angle was used during actual testing to insure that each subject was performing a consistent landing technique for each test condition based on the method described by Zhang et al. (2000). Subjects performed five drop landing trials after the initial three trials from an overhead bar in each of six test conditions. Three of the test conditions in the first protocol (PT1) included drop landings from heights of 40, 60, and 80 cm. The remaining three conditions for the second protocol (PT2) included landing from three heights based on 70%, 100%, and 130% of the individual subject's MVJ. The order of the two protocols was first randomized and the test conditions were then randomized within each testing protocol. Simultaneous recording of three-dimensional (3D) kinematics, electrogoniometer, and ground reaction forces (GRF) were conducted.

Instrumentation. A six-camera motion analysis system (120 Hz, Vicon, Oxford, UK) was used to collect 3D kinematics from the right side of the subjects during the second test session. The mean residual error associated with the calibration for each subject was 0.890 mm (±0.109 mm). A cluster of four retro-reflective tracking markers attached to a rigid thermoplastic shell was placed on the thigh and leg via Neoprene wraps [30, 31]. Other tracking markers were attached directly to the shoe and pelvis via a separate Neoprene wrap. Additional retro-reflective markers were secured to the skin at the left and right sides of the pelvis, the lateral greater trochanters, and the medial and lateral sides of the femoral condyles, the malleoli, and the head of the fifth and first metatarsal to determine the joint centers. The hip joint center was estimated using a modified method proposed by Seidel [32]. The right hip joint center was located at a position that is 14% of pelvic width (distance between the right and left ASISs), from the right ASIS, pelvic height 34% pelvic depth (between ASIS and PSIS) from the ASIS, and at the height of the greater trochanter.

A force platform (1080 Hz; OR6-7, AMTI) was used to measure the GRF and the moments of forces during the testing trials. The subjects were instructed to perform their respective drop landings with only the right foot landing on the force platform and the left foot landing on the adjacent floor flush with force platform.

Data Analysis. The 500 ms of the kinematic signals obtained during the data collection were analyzed and filtered at 8 Hz cutoff frequency using a fourth order Butterworth lowpass filter. GRF data were filtered using a fourth order Butterworth lowpass filter at 20 Hz cutoff frequency. Selected GRF variables, linear and angular kinematic and kinetic variables were computed or determined using Visual 3D (C-

Motion, Gaithersburg, MD), and a customized computer program (Microsoft Visual Basic 6.0) determined critical events for the peak GRF forces and the three lower extremity joint kinematics and kinetics in each of the vertical, medial-lateral, and anterior-posterior planes. As measured in the sagittal plane, a static erect posture with the trunk, thigh, and leg in a strait line and the foot at a right angle to the leg corresponds to zero degrees at the hip, knee and ankle. By convention of the right hand rule, extension, abduction, and internal rotation angles were all considered to be positive. Hip, knee, and ankle joint extension moments, adduction and external rotation moments were negative. A negative joint power or work is indicative of energy absorption. All GRF and joint kinetic variables were normalized by potential energy.

A 2 × 2 × 3 (Group × Protocol × Height) mixed design repeated measures ANOVA with Group as the between subject factor was used to evaluate selected kinematic, GRF, and kinetic variables (SPSS, Carrie, NC) with the alpha level set at $p < 0.05$. Separate ANOVAs were conducted on each group for variables that demonstrated a significant Group × Protocol or Group × Height interactions and a pairwise t-test was performed on any variables demonstrating a Protocol × Height interaction. Regression analyses including linear, quadratic and cubic models were performed on selected peak GRF variables.

Results

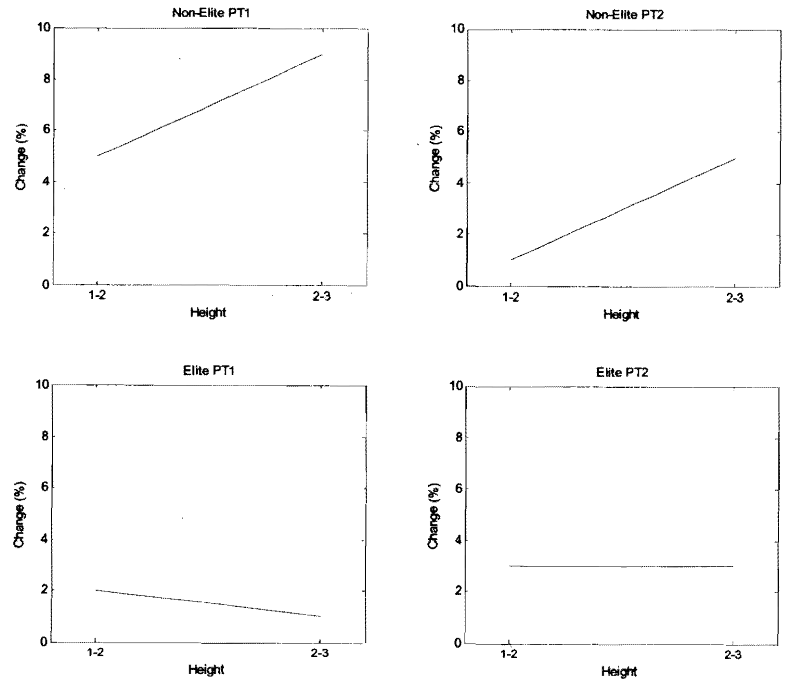
On average the non-elite athletes landed from heights of 33.20, 47.43 and 61.66 cm for the second protocol, while the average landing heights for elite athletes in the second protocol were 49.22, 70.31 and 87.69 cm. All subjects possessed a typical toe-heel landing style with the first peak associated with the toe touchdown and the second peak associated with the heel touchdown. The ANOVA revealed a significant Group × Protocol interaction for second GRF peak that decreased significantly from PT1 to PT2 in the elite athletes only (Table 1). The loading rate for the second GRF peak was significantly greater for the non-elite athletes than the elite athletes. The percent change in the first and second GRF peaks are presented in Figure 1. There were no significant regression models to describe the effect of height on the first GRF peak for PT1 and PT2. However, the regression analysis revealed that a linear model ($R^2 = 0.328$, $p = 0.000$) compared to a quadratic ($R^2 = 0.331$, $p = 0.000$) or cubic ($R^2 = 0.331$, $p = 0.000$) model was the best fit to describe the effect of landing height on the second GRF peak for PT1 due to fact that the quadratic and cubic terms contributed little to the significance of the model (Figure 2a). On the other hand, a cubic regression model best described the effects of landing height on the second GRF peak for PT2 ($R^2 = 0.556$, $p = 0.000$) compared to a quadratic ($R^2 = 0.541$, $p = 0.000$) or linear ($R^2 = 0.485$, $p = 0.000$) model because of the higher R^2 value indicating a better fit (Figure 2b) ($p < 0.05$).

The maximum hip extension moment was significantly greater for the non-elite athletes (Table 2). The ANOVA revealed a significant Group × Protocol interaction for the maximum knee adduction and the maximum ankle plantarflexion moment. The knee adduction and ankle plantarflexion moments decreased significantly from PT1 to PT2 for the elite athletes and increased significantly from PT1 to PT2 for the non-elite athletes (Table 2). No significant differences or interactions were observed for the knee extension, hip abduction or ankle adduction moments for either group.

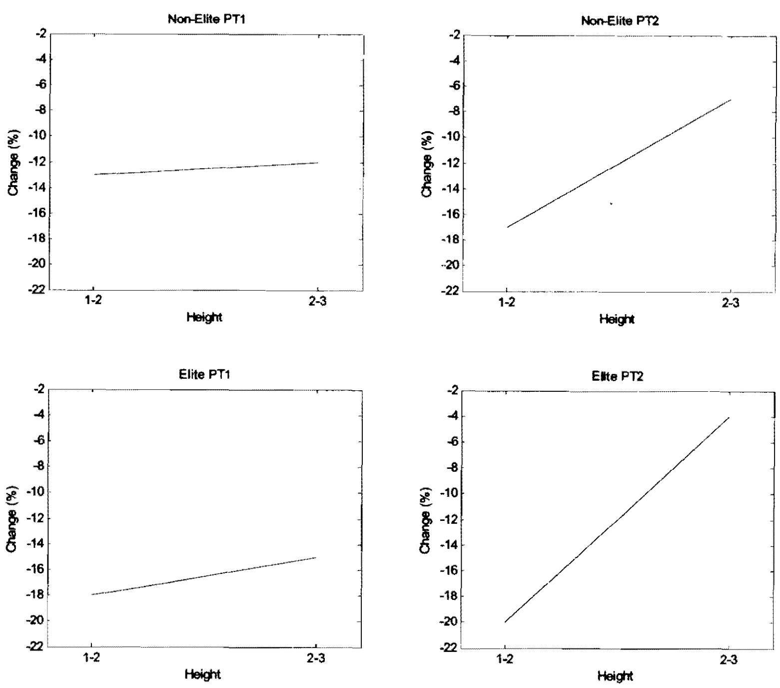
Table 1. Mean maximum GRF variables: means ± standard deviations.

Group	Protocol	Height	F1	F2[b]	LRate1	LRate2[*]
Non Elite	PT1	40	2.68±0.58	6.09±1.12	369.72±155.53	132.83±49.13
		60	2.81±0.53	5.29±0.39	377.25±143.17	140.43±31.52
		80	3.07±0.32	4.67±0.60	446.84±145.57	142.66±36.94
	PT2	70%	2.73±0.60	6.99±1.67	294.26±148.90	135.41±54.87
		100%	2.75±0.35	5.78±0.91	429.01±231.24	127.93±42.90
		130%	2.90±0.53	5.27±0.54	399.25±160.05	126.97±47.03
Elite	PT1	40	2.81±0.62	5.39±0.94	296.87±66.38	91.11±31.50
		60	2.87±0.48	4.40±0.86	326.19±64.65	90.75±31.88
		80	2.90±0.64	3.74±0.95	381.49±132.51	91.80±48.59
	PT2	70%	2.71±0.54	4.75±1.33	285.87±82.01	90.49±47.83
		100%	2.81±0.51	3.82±1.01	327.39±83.56	81.06±40.51
		130%	2.89±0.75	3.63±0.97	431.27±179.01	99.02±45.01

Note: PT1 = absolute heights; PT2 = %MVJ; Force units is $N \cdot J^{-1}$; Loading Rate units is $N \cdot s^{-1} \cdot J^{-1}$; F1 = the first GRF peak associated with the toe touchdown; F2 = the second GRF peak associated with heel touchdown; LRate1 = the loading rate for F1; F2 = the loading rate for F2; [*]: Significantly different from non-elite ($p<0.05$); [a]: Significantly different from protocol 1for non-elite; [b]: Significantly different from protocol 1for elite; ($p<0.05$).

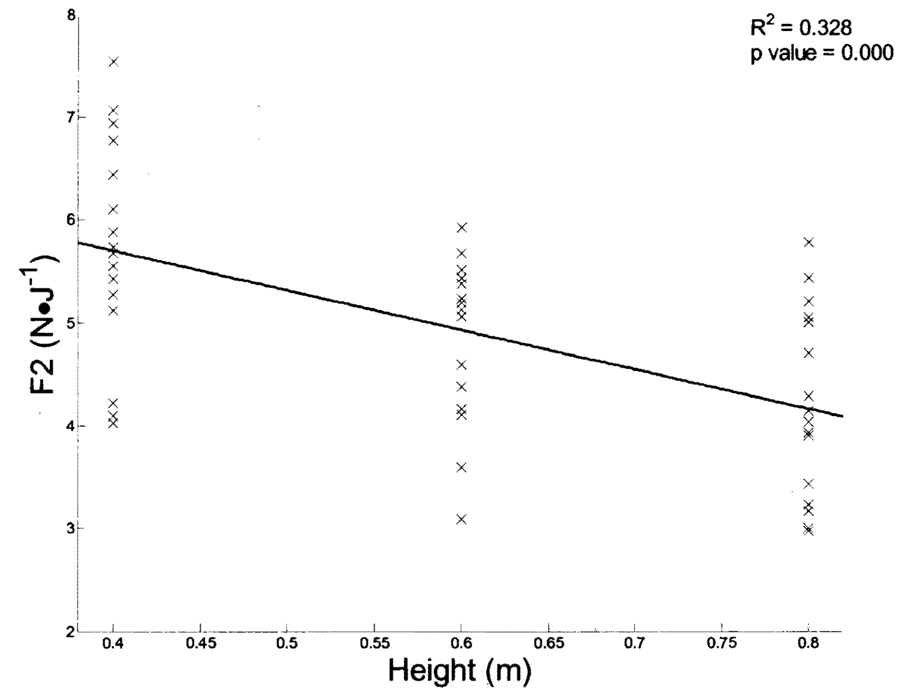


(a)

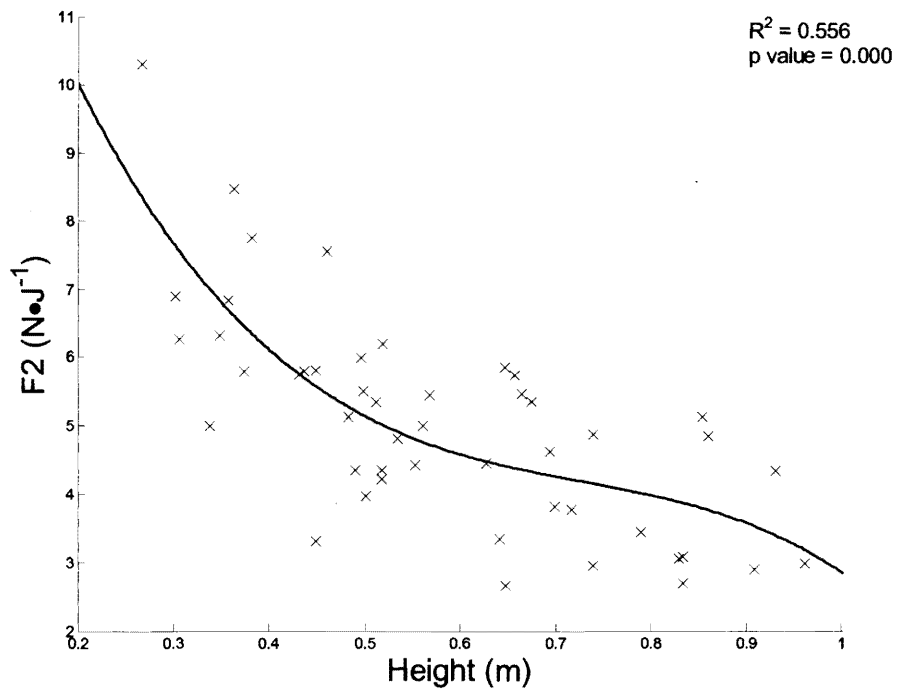


(b)

Figure 1. Percent change for (a) F1 and (b) F2; the percent change were calculated from height 1 to height 2 and height 2 to height 3.



(a)



(b)

Figure 2. Regression results for the effect of landing height on (a) the second GRF peak (F2) for PT1 and (b) F2 for PT2.

Table 2. Mean peak hip extension, ankle plantarflexion, and knee adduction moments: means ± standard deviations.

Group	Protocol	Height	Hip Extension*	Ankle Plantarflexion [a,b]	Knee Adduction [a,b]
Non Elite	PT1	40	-0.87±0.27	-0.39±0.13	-0.13±0.05
		60	-0.75±0.21	-0.28±0.08	-0.10±0.07
		80	-0.63±0.26	-0.22±0.05	-0.09±0.06
	PT2	70%	-0.91±0.38	-0.44±0.13	-0.16±0.07
		100%	-0.83±0.32	-0.35±0.09	-0.15±0.06
		130%	-0.82±0.22	-0.27±0.08	-0.09±0.06
Elite	PT1	40	-0.66±0.18	-0.47±0.08	-0.16±0.09
		60	-0.57±0.12	-0.32±0.05	-0.12±0.06
		80	-0.49±0.21	-0.25±0.04	-0.09±0.05
	PT2	70%	-0.74±0.23	-0.36±0.05	-0.13±0.07
		100%	-0.58±0.14	-0.28±0.05	-0.11±0.07
		130%	-0.49±0.20	-0.23±0.06	-0.09±0.06

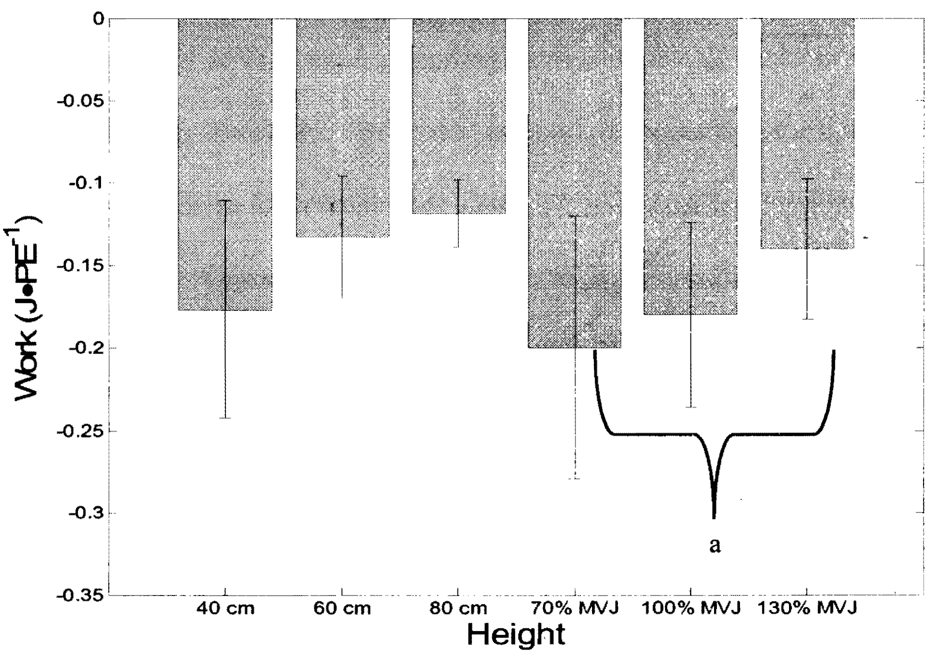
Note: PT1 = absolute heights; PT2 = %MVJ; Peak moment unit is $N \cdot m \cdot J^{-1}$; [a] Significantly different from protocol 1for non-elite; [b] Significantly different from protocol 1for elite; * Significantly different from non-elite; $p<0.05$.

The ankle eccentric work for the non-elite athletes increased significantly from PT1 to PT2 (Figure 3a) and decreased significantly for the elite athletes (Figure 3b). The Group × Protocol interaction between the ankle joint work and the height showed an increase for the non-elite group and a decrease for the elite group (Figure 4). No significant differences or interactions were found for the knee or hip joint work.

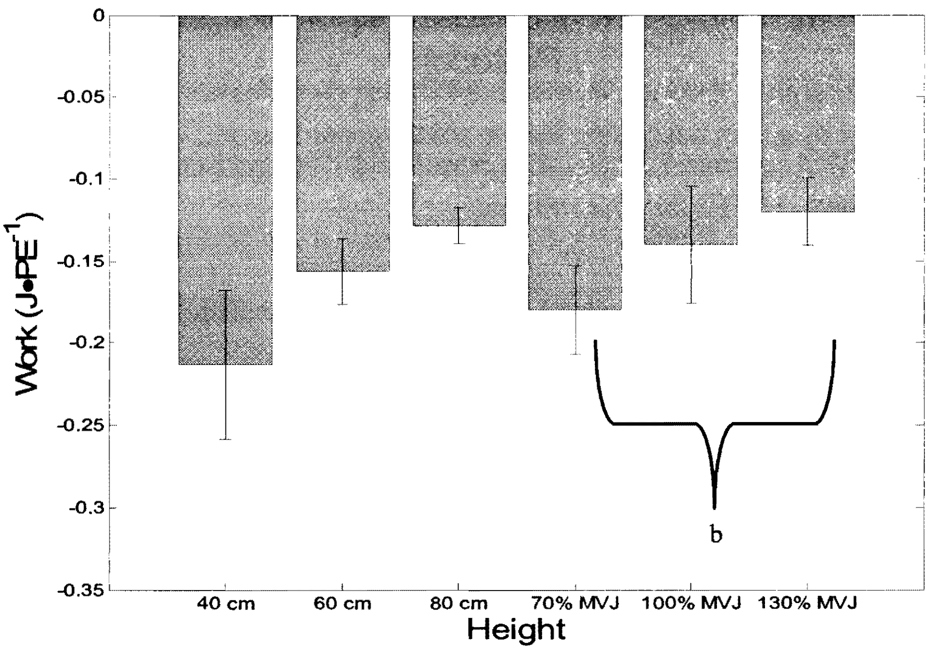
Discussion

It was hypothesized that athletes who participate regularly in sports that require jumping or who train for power would be better suited in attenuating the impact forces associated with landing. Hoffman et al. (1997) concluded that experienced parachute jumpers use their power generation capabilities more effectively than novice parachute jumpers during the impact phase of landing due to the high correlation between a one repetition maximum squat and peak GRF variables. To our knowledge this is the first time that an accepted method of power generation capabilities (i.e. MVJ) has been used to distinguish between two groups of recreational athletes in examining the 3D kinetics of the lower extremity joints during landings. In this study it was demonstrated that the elite athletes demonstrated less mechanical responses and used their hip muscles less in dissipating the loads during landing compared to the non-elite athletes.

Typically in landing studies minimization of the variation due to individual differences in body weight is accomplished by one of several normalization schemes including: normalization of GRF and joint moment variables by multiples of body weight (BW) and body mass, respectively [12, 14] or normalization of both GRF and moments



(a)



(b)

Figure 3. Mean ankle eccentric work for (a) non-elite athletes and (b) elite athletes; [a] Significantly different from protocol 1 for non-elite; [b] Significantly different from protocol 1 for elite; ($p<0.05$).

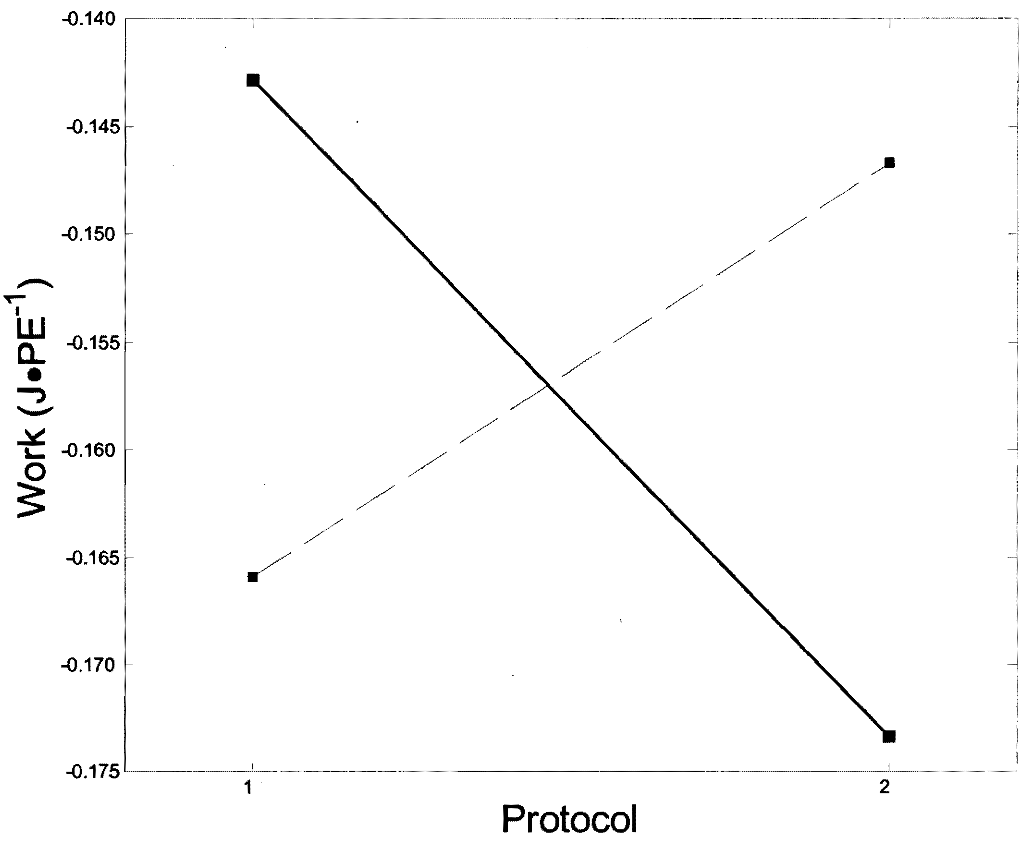


Figure 4. Protocol by group interaction for the ankle eccentric work; —— non-elite athletes; ----- elite athletes; PT1 increased significantly to PT2 non-elite athletes; PT1 decreased significantly to PT2 for elite athletes.

by body mass [16, 44]. However, there is a confounding problem when a protocol based on percentages of MVJ is used in landing studies in that all subjects are landing from different heights. Therefore a proposed method of accounting for the different landing heights in addition to individual body masses is to normalize the dependent variable by potential energy. One study showed that traditional normalization methods yielded statistically insignificant differences in selected GRF variables, but normalization by potential energy proved effective in demonstrating statistical differences in GRF variables in two types of shoes during jumping activities [38]. Hence, all GRF and kinetic variables in the present study were normalized by potential energy.

McNitt-Gray (1993) and Zhang et al. (2000) demonstrated that as the height of landing increases the peak GRF forces increased. Both the first GRF peak and the loading rate for the first GRF peak increased for both groups as the landing height increased, yet the touchdown peak GRF decreased for both groups (Table 1). The difference observed between the literature and our findings may be due to the normalization scheme used. Zhang and colleagues (2000) showed that the two peak GRFs responded differently with increasing landing heights and reported that the average and relative increases with respect from lowest height (0.32 m) was 136% for the first GRF peak and 44% for the second GRF peak. They concluded this may be indicative of a Newtonian/mechanical response without much neuromuscular intervention. Moreover, both Devita and Skelly (1992) and Zhang and his colleagues (2000) agreed that the second GRF peak occurs much later after the first impact allowing more time for the lower extremity muscles to absorb the impact. Our results for the first GRF peak and the second GRF peak (Table 1 & Figure 1) suggests that the elite athletes may be anticipating the impact force before touchdown and thereby increasing the tension in the lower extremities to dissipate the load after impact where as the non-elite athletes incorporate more of a mechanical response in dissipating the load. This assertion is further substantiated by the fact that the loading rate for the second GRF peak was significantly smaller for the elite athletes.

The hypothesis that the elite athletes are more capable of attenuating impact forces during landing was also supported by the joint kinetic results. The elite group demonstrated a significantly smaller hip extension moment that suggests that the non-elite athletes eccentrically contract their hip extensors more to help attenuate the impact loading. From PT1 to PT2 the non-elite athletes increased contributions in the ankle muscle group (26.9% to 32.1%) and maintained contributions from the knee muscle group (52.9% to 51.4%), and decreased contributions from the hip muscle group (20.2% to 16.5%). However, for the elite athletes there was a decreased contribution by the ankle muscle group (38.0% to 32.4%) and the knee and hip extensors increased contributions from 47.5% to 50.1% and 14.5% to 17.6% respectively to the total energy dissipation during landing from PT1 to PT2. These results suggest that the non-elite and the elite athletes use a different strategy of joint kinetics to dissipate the impact loads from landing. Specifically, the non-elite athletes generate greater tension in their hip musculature. Additionally, the contribution of the non-elites' knee musculature remains almost the same regardless of the landing height while the demand on the ankle and hip muscle group changes with changes in landing heights. However, the elite athletes generate less tension in the hip muscles and the contributions from the three lower extremity joint musculature changes with landing heights. The differences observed between the non-elite and the elite athletes in the hip joint moments and the contributions from the lower extremity muscle groups offer further support to the hypothesis that elite athletes attenuate the impact loads from landing differently.

A second hypothesis tested in this study was that the non-elite and elite athletes would respond differently when landing using the protocol based on the absolute heights compared to the protocol based on the percentages of the subject's MVJ. The GRF results demonstrated that the second GRF peak decreased significantly for the elite athletes and an insignificant increase was observed for non-elite athletes from PT1 to PT2 (Table 1). Some increases across the heights for the first GRF peak were also observed in the non-elite athletes in both protocols but none were seen in the elite athletes (Figure 1). Both the ankle plantarflexion and knee adduction moments were significantly greater in PT2 for the non-elite athletes and in PT1 for the elite athletes (Table 2). Further, the significant protocol by group interaction effect observed in the mean ankle eccentric work showed a significant increase for the non-elite athletes but a significant decrease for the elite athletes from PT1 to PT2 (Figure 3 & 4). These results strongly support the hypothesis that the two groups of athletes responded differently to the two different protocols. The differences observed in the two groups of athletes across the two protocols can be partially attributed to the landing heights. As reported previously, the average landing height for the non-elite athletes was 33.20, 47.43 and 61.66 cm for PT2 and 49.22, 70.31 and 87.69 cm for the elite athletes for PT2, while both groups landed from 40, 60 and 80 cm in PT1. Further support to the theory was provided in the previous paragraphs which demonstrated that non-elite athletes have more of a

Newtonian/mechanical response and a different strategy of joint kinetics to landing when compared to elite athletes.

Two interesting findings related to the original intent of this study were also realized. As stated previously, both Devita and Skelly (1992) and Zhang and colleagues (2000) suggested that the time delay between the first GRF peak and the second GRF peak may allow for more of a neuromuscular reaction from the lower extremity muscles to aid in the dissipation of the impact forces. It was presented that neither a linear, quadratic or cubic model could significantly describe the effect of landing height on the first GRF peak but there appears to be a linear decrease in the second GRF peak for PT1 as height increases (Figure 2a). Also, a cubic regression model proved to be the better fit for the effect of landing height on the second GRF peak for PT2 compared to a linear and quadratic model (Figure 2b). These findings offer further support to the theory proposed by both Devita and Skelly (1992) and Zhang and colleagues (2000). Specifically, as height increased the magnitude of the second GRF peak for both protocols decreased, which suggests that there is more of a neuromuscular reaction from the lower extremity muscles as the landing height increases. Further, at the lower landing heights there is more of a Newtonian/mechanical response but at the higher heights the subjects may be using more of neuromuscular response to attenuate the loads at impact. The normalization of the GRF variables by potential energy revealed that there was a cubic response in the second GRF peak as height increased, which otherwise may not have been realized if a different normalization scheme was chosen.

Another interesting finding was that the non-elite athletes generated significantly greater tension in the hip extensor muscles compared to the elite athletes. McNitt-Gray

(1993) asserted that gymnasts generate greater hip extension moments when compared to recreational athletes to maintain their balance and that recreational athletes may be incapable of producing large extensor moments. McNitt-Gray (1993) offered that one possible explanation for the discrepancy is that the gymnasts generate larger hip extension moments because of the demands of the sport to reduce the hip angular momentum after contact. In other words, gymnasts generate larger hip moments to help them "stick" the landing as required by competition, which is not necessary for the recreational athletes in their study. This is not necessarily the case for the elite athletes in this study instead the elite athletes who participate in sports such as basketball or volleyball are used to repetitive attempts to collect a single rebound or block one shot at the net. Hence, the cessation of all angular momentum would prove to be disadvantageous in such sports in that the elite athletes in our study may be used to using some of the angular momentum generated during the landing to actually aid them in performing a second or third attempt at a rebound or blocked shot. Conversely, the non-elite athletes in our study who participate in non-jumping sports would naturally desire to come to a complete stop from a landing. This may explain why the elite athletes in our study produced smaller hip moments compared to the non-elite athletes.

It was demonstrated in this study that the elite athletes are better suited for attenuating impact loads during landings and that the non-elite and elite athletes respond differently to two different landing protocols. The findings presented in this study suggest that care should be taken in subject selection and the protocol used when investigating impact attenuation during landing. Using subjects who are inexperienced in jumping/landing activities as a subject population in addition to employing a protocol based on their MVJ may not be sufficient in making inferences about the dependent variables in question. The fact that non-elite athletes appear to have more of a Newtonian/mechanical response and a different joint kinetic landing strategy compared to elite athletes suggests that training for power may reduce the demands placed on the body during landing and thereby reduce the potential risk of injury.

Acknowledgements

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References

1. Ferretti, A., et al., *Knee ligament injuries in volleyball players.* Am J Sports Med, 1992. **20**(2): p. 203-7.
2. Gray, J., et al., *A survey of injuries to the anterior cruciate ligament of the knee in female basketball players.* Int J Sports Med, 1985. **6**(6): p. 314-6.
3. Hewett, T.E., et al., *The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study.* Am J Sports Med, 1999. **27**(6): p. 699-706.
4. Arendt, E. and R. Dick, *Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature.* Am J Sports Med, 1995. **23**(6): p. 694-701.
5. Huston, L.J. and E.M. Wojtys, *Neuromuscular performance characteristics in elite female athletes.* Am J Sports Med, 1996. **24**(4): p. 427-36.
6. Kreighbaum, E. and K.M. Barthels, *Performance Analysis of Pushlike Movements*, in *Biomechanics: A Qualitative Approach for Studying Human Movement.* 1996, Allyn and Bacon: Boston. p. 619.
7. Dowling, J.J. and L. Vamos, *Identification of Kinetic and Temporal Factors Related to Vertical Jump Performance.* Journal of Applied Biomechanics, 1993. **9**(2): p. 95-110.
8. McBride, J.M., et al., *The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed.* J Strength Cond Res, 2002. **16**(1): p. 75-82.
9. Stone, M.H., et al., *Power and maximum strength relationships during performance of dynamic and static weighted jumps.* J Strength Cond Res, 2003. **17**(1): p. 140-7.
10. Fatouros, I.G.J., A.Z.; Leontsini, D.; and K.A. Taxildaris, N.; Kostopoulos, N.; Buckenmeyer, P., *Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength.* Journal of strength and conditioning research, 2000. **14**(4): p. 470-476.
11. Luebbers, P.E., et al., *Effects of plyometric training and recovery on vertical jump performance and anaerobic power.* J Strength Cond Res, 2003. **17**(4): p. 704-9.
12. Dufek, J.S. and B.T. Bates, *The evaluation and prediction of impact forces during landings.* Med Sci Sports Exerc, 1990. **22**(3): p. 370-7.
13. Gross, T.S. and R.C. Nelson, *The shock attenuation role of the ankle during landing from a vertical jump.* Med Sci Sports Exerc, 1988. **20**(5): p. 506-14.
14. McNitt-Gray, J.L., *Kinetics of the lower extremities during drop landings from three heights.* J Biomech, 1993. **26**(9): p. 1037-46.
15. Self, B.P. and D. Paine, *Ankle Biomechanics During Four Landing Techniques.* Medicine & Science in Sports & Exercise, 2001. **33**(8): p. 1338-1344.
16. Zhang, S., B.T. Bates, and J.S. Dufek, *Contributions of Lower Extremity Joints to Energy Dissipation During Landings.* Medicine and Science in Sports and Exercise, 2000. **32**(4): p. 812-819.

17. Arampatzis, A., G.P. Bruggemann, and G.M. Klapsing, *A three-dimensional shank-foot model to determine the foot motion during landings.* Med Sci Sports Exerc, 2002. **34**(1): p. 130-8.
18. Hass, C.J., et al., *Lower Extremity Biomechanics Differ in Prepubescent and Postpubescent Female Athletes During Stride Jump Landings.* Journal of Applied Biomechanics, 2003. **19**: p. 139-152.
19. Chappell, J.D., et al., *A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks.* Am J Sports Med, 2002. **30**(2): p. 261-7.
20. Decker, M.J., et al., *Gender differences in lower extremity kinematics, kinetics and energy absorption during landing.* Clin Biomech (Bristol, Avon), 2003. **18**(7): p. 662-9.
21. Lephart, S.M., et al., *Gender differences in strength and lower extremity kinematics during landing.* Clin Orthop, 2002(401): p. 162-9.
22. Hewett, T.E., et al., *Plyometric Training in Female Athletes Decreased Impact Forces and Increased Hamstring Torques.* The American Journal of Sports Medicine, 1996. **24**(6): p. 765-773.
23. Huston, L.J., et al., *Gender differences in knee angle when landing from a drop-jump.* Am J Knee Surg, 2001. **14**(4): p. 215-9; discussion 219-20.
24. Fagenbaum, R. and W.G. Darling, *Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury.* Am J Sports Med, 2003. **31**(2): p. 233-40.
25. Ford, K.R., G.D. Myer, and T.E. Hewett, *Valgus knee motion during landing in high school female and male basketball players.* Med Sci Sports Exerc, 2003. **35**(10): p. 1745-50.
26. Hoffman, J.R., D. Liebermann, and A. Gusis, *Relationship of leg strength and power to ground reaction forces in both experienced and novice jump trained personnel.* Aviat Space Environ Med, 1997. **68**(8): p. 710-4.
27. Hunter, J.P. and R.N. Marshall, *Effects of power and flexibility training on vertical jump technique.* Med Sci Sports Exerc, 2002. **34**(3): p. 478-86.
28. James, C.R., J.S. Dufek, and B.T. Bates, *Effects of injury proneness and task difficulty on joint kinetic variability.* Med Sci Sports Exerc, 2000. **32**(11): p. 1833-44.
29. Ross, S.E. and K.M. Guskiewicz, *Examination of Static and Dynamic Postural Stability in Individuals With Functionally Stable and Unstable Ankles.* Clin J Sport Med, 2004. **14**(6): p. 332-338.
30. Manal, K., et al., *Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study.* Gait Posture, 2000. **11**(1): p. 38-45.
31. McClay, I. and K. Manal, *Three-dimensional kinetic analysis of running: significance of secondary planes of motion.* Med Sci Sports Exerc, 1999. **31**(11): p. 1629-37.
32. Seidel, G.K., et al., *Hip joint center location from palpable bony landmarks--a cadaver study.* J Biomech, 1995. **28**(8): p. 995-8.
33. Garhammer, J., *Weight Lifting and Training*, in *Biomechanics of Sport*, C.L. Vaughan, Editor. 1989, CRC Press: Boca Raton. p. 169-212.

34. Baechle, T.R. and R.W. Earle, *The Biomechanics of Resistance Exercise*, in *Essentials of Strength Training and Conditioning*. 2000, Human Kinetics: Champaign, IL. p. 25-56.
35. Driss, T., et al., *Effects of external loading on power output in a squat jump on a force platform: a comparison between strength and power athletes and sedentary individuals.* J Sports Sci, 2001. **19**(2): p. 99-105.
36. Radin, E.L. and I.L. Paul, *Response of joints to impact loading. I. In vitro wear.* Arthritis Rheum, 1971. **14**(3): p. 356-62.
37. Hass, C.J., et al., *Knee biomechanics during landings: comparison of pre- and postpubescent females.* Med Sci Sports Exerc, 2005. **37**(1): p. 100-7.
38. Zhang, S., K. Clowers, and C. Kohstall, *Impact Attenuation and Kinetic Characteristics of Training Shoes in Landing and Jumping Activities*, in *2005 Annual Conference of American College of Sports Medicine*. 2005: Nashville, TN.
39. Kadaba, M.P., H.K. Ramakrishnan, and M.E. Wootten, *Measurement of Lower-Extremity Kinematics During Level Walking.* Journal of Orthopaedic Research, 1990. **8**(3): p. 383-392.
40. Karlsson, D. and R. Tranberg, *On skin movement artefact-resonant frequencies of skin markders attached to the leg.* Human Movement Science, 1999. **18**: p. 627-625.
41. Reinschmidt, C., et al., *Effect of skin movement on the analysis of skeletal knee joint motion during running.* J Biomech, 1997. **30**(7): p. 729-32.
42. Grood, E.S. and W.J. Suntay, *A joint coordinate system for the clinical description of three-dimensional motions: application to the knee.* J Biomech Eng, 1983. **105**(2): p. 136-44.
43. Vaughan, C.L., *Dynamics of Human Gait.* 2nd ed. 1999, Cape Town: Kiboho Publishers. 141.
44. Devita, P. and W.A. Skelly, *Effect of landing stiffness on joint kinetics and energetics in the lower extremity.* Med Sci Sports Exerc, 1992. **24**(1): p. 108-15.
45. Agel, J., E.A. Arendt, and B. Bershadsky, *Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review.* Am J Sports Med, 2005. **33**(4): p. 524-30.
46. Clowers, K. and S. Zhang, *Effects of Power Generation on Lower Extremity Landing Biomechanics.* 2005, Unpublished Dissertation. p. 22.

Part IV

Effects of Gender and Power Generation on Impact Attenuation During Landing Activity

Abstract

Background. Few studies have examined the effects of power generation capabilities on impact attenuation during landing. The purpose of this study was to investigate effects that gender and power generation capacity have on impact attenuation in landing activities.

Methods. Thirty two recreational athletes were divided into four groups: eight elite males, eight non-elite males, eight elite females and eight non-elite females performed five drop landing trials from three heights in each of two different test protocols: from landing heights of 40, 60, and 80 cm in the first protocol (PT1) and from 70%, 100%, and 130% of their maximum vertical jump height in the second protocol (PT2). Ground reaction force (GRF) and three-dimensional kinematic data were recorded simultaneously. Selected variables were evaluated using a mixed design three-way repeated measures ANOVA (Group × Gender × Protocol × Height) with Group and Gender as the between-subject factors ($p < 0.05$).

Findings. Results indicated a significantly greater and smaller peak heel-touchdown GRF for the female non-elite athletes and the male elite athletes, respectively, compared to their counterparts. Elite females landed with greater knee contact and maximum flexion angles compared to the elite males, while the same angles were greater for the non-elite males compared to the non-elite females. The ankle eccentric work demonstrated a significant interaction for each group of the non-elite athletes and there was only a significant interaction for the non-elite females for the knee eccentric work.

Interpretation. The results suggest that the elite male athletes may be more capable at attenuating the impact forces during landing and the female and male subjects may have different neuromuscular control patterns to dissipate the impact loads.

Key Words: gender differences, impact attenuation, kinetics

Introduction

Knee ligament injuries occur most often as a result of landing from a jump [1, 2]. Moreover, studies have shown that female athletes accrue more knee injures when compared to their male counterparts [4, 5] and that the incidence rate of knee injuries in females is four to six times higher than males [2-5]. The rate of non-contact ACL injuries was reported as high as 0.13 and 0.16 per 1000 exposures in female soccer and basketball players, respectively [45].

Many studies have investigated the disparity between the gender injury rate by examining the kinematics, GRF, and kinetics during landing activities. Past research has reported that females had significantly less knee flexion at contact compared to matched male athletes [20, 21, 23] while others documented that females had significantly higher knee flexion angles at contact [24]. It has also been shown that male and female subjects landed with similar maximum knee flexion angles [20] and knee range of motion [23]. However, females have been shown to exhibit both greater hip internal rotation, less leg internal rotation [21], and higher knee valgus motion [25]. In addition, it was reported that prepubescent girls landed with significantly greater knee flexion compared to postpubescent women [37]. Studies comparing gender differences in the vertical ground reaction forces (GRF) during landing have shown no significant differences [20, 21], but one study reported women having significantly greater peak proximal tibia anterior shear force during landing [19]. However, after participating in a jump training program women exhibited significantly lower peak GRF during landing activities than untrained males [22]. Studies reporting kinetic differences have shown that female athletes have significantly smaller peak knee flexion/extension torque than matched males [21] and smaller peak knee adduction, peak knee abduction, and knee extension moments during landing when compared to untrained males [22]. Also, the peak knee extensor moments for prepubescent females has been shown to be significantly greater during landing compared to postpubescent females [37].

Few studies have examined the effects of power generation and/or training levels on the biomechanical characteristics of the lower extremity during landing. One study reported that there was a correlation between leg strength and the second maximum peak GRF in experienced parachutists compared to non-experienced parachutists [26]. Hunter demonstrated that individuals who train for power have decreased total body stiffness upon landing [27]. Athletic skills such as rebounding in basketball or spiking in volleyball require a sequential application of musculotendinous power in the lower extremity joints to successfully lift the body off the ground. The vertical jump is a common method to measure individual power outputs in the lower extremity [7]. In addition to the lack of studies on effects of power generation on impact attenuation, gender differences in this regard are also unknown in landing activities. Therefore the purpose of this study was to investigate effects that gender and power generation capacity have on impact attenuation in landing activities. It was hypothesized that the female athletes and the non-elite athletes would be less capable attenuating impact forces during landing compared to the male and elite athletes.

Methods

Subjects. A total of 32 subjects who met the following inclusion criteria were placed into one of two experimental groups. Eight male subjects (age: 22.25±1.49 years, mass: 86.43±12.29 kg, height: 1.85±0.06 m) who jumped 64 cm or higher and eight female subjects (age: 22.25±1.99 years, mass: 61.34±4.77 kg, height: 1.66±0.05 m) who jumped 48 cm or higher and had self reported activities of either basketball, volleyball, or weightlifting three or more times a week were placed in the elite group. Eight male subjects (age: 24.00±2.83 years, mass: 78.34±8.18 kg, height: 1.82±0.04 m) who jumped 54 cm or less and eight female subjects (age: 22.63±3.25 years, mass: 59.03±7.40 kg, height: 1.67±0.03 m) who jumped 38 cm or less and did not participate in any jumping/landing movements regularly were placed in the non-elite group. The cut-off jump height for each group was determined based on a method described by Clowers et al. (2005). Written informed consent approved by the Institution Review Board at The University of Tennessee was obtained from the subjects prior to their participation in the test session.

Experimental Protocol. Subjects performed five drop landing trials after the initial three trials from an overhead bar in each of six test conditions [46]. Three of the test conditions in the first protocol (PT1) included drop landings from heights of 40, 60, and 80 cm. The remaining three conditions for the second protocol (PT2) included landing from three heights based on 70%, 100%, and 130% of the individual subject's

MVJ. Randomization of the two protocols was performed first followed by the randomized test conditions (landing heights) within each test protocol. Simultaneous recording of three-dimensional (3D) kinematics, electrogoniometer, and ground reaction forces (GRF) were conducted.

Instrumentation. A six-camera motion analysis system (120 Hz, Vicon, Oxford, UK) was used to collect 3D kinematics from the right side of the subjects during the second test session for which the mean residual error associated with the calibration for each subject was 0.922 mm (±0.089 mm). A force platform (1080 Hz; OR6-7, AMTI) was used to measure the GRF and the moments of forces during the testing trials. A cluster of four retro-reflective tracking markers attached to a rigid thermoplastic shell was placed on the thigh and leg via Neoprene wraps and other tracking markers were attached directly to the shoe and pelvis via a separate Neoprene wrap. In order to determine the joint centers, additional retro-reflective markers were secured to the skin at the left and right sides of the pelvis, the lateral greater trochanters, and the medial and lateral sides of the femoral condyles, the malleoli, and the head of the fifth and first metatarsal.

Data Analysis. Selected GRF variables, linear and angular kinematic and kinetic variables were computed using Visual 3D (C-Motion, Gaithersburg, MD). A customized computer program (Microsoft Visual Basic 6.0) was used to determine critical events for the peak GRF forces and the three lower extremity joint kinematics and kinetics. The manner in which the drop landings were analyzed was described in detail elsewhere [46].

A 2 ×2 × 2 × 3 (Gender × Group × Protocol × Height) mixed design repeated measures ANOVA with Group and Gender as between subject factors was used to evaluate selected kinematic, GRF, and kinetic variables (SPSS, Carrie, NC) with alpha level set at $p < 0.05$. On any variable that demonstrated a Gender × Protocol or Group × Protocol interaction, a follow-up one-way ANOVA was conducted on each factor.

Results

The mixed design ANOVA revealed a significant Gender × Protocol interaction for the peak heel touchdown GRF that decreased significantly from PT1 to PT2 for the elite males and the non-elite females only (Figure 1). A Group × Protocol interaction was also observed for the same peak. The subsequent follow-up comparisons revealed a significant decrease from PT1 to PT2 for the non-elite athletes only and a significantly smaller F2 for the elite athletes in PT2 compared to the non-elite athletes. The percent change from the lowest height in PT1 and PT2 for the first and second GRF peaks for the non-elite and elite athletes is depicted in Figure 2.

The ANOVA revealed a significant Gender × Protocol interaction for the knee flexion contact angle and maximum knee flexion angle (Figure 3). Subsequent analyses revealed that both variables were significantly greater in PT1 for the non-elite male and the non-elite female athletes while for the elite male athletes the same angles were significantly greater in PT2 (Table 1). The maximum knee flexion decreased significantly from PT1 to PT2 in the elite female athletes (Table 1). The maximum knee adduction angle decreased significantly from PT1 to PT2 for the non-elite female athletes only (Table 1). A significant Group × Protocol interaction was found for the knee flexion contact angle, maximum knee flexion angle, and maximum knee adduction angle for

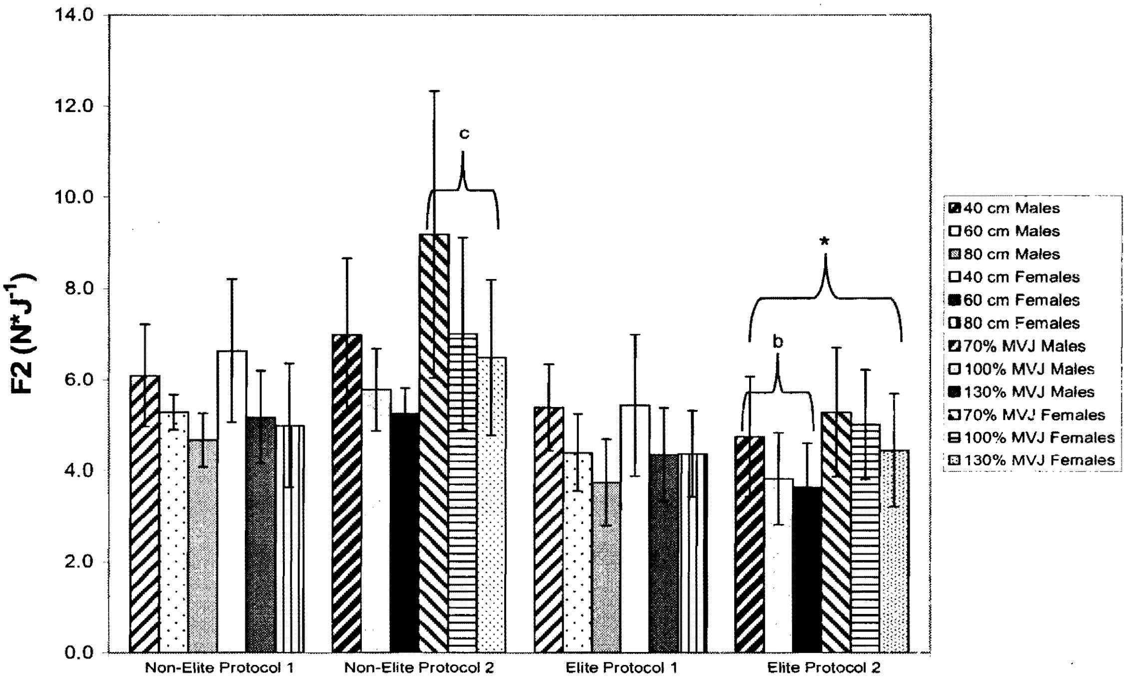
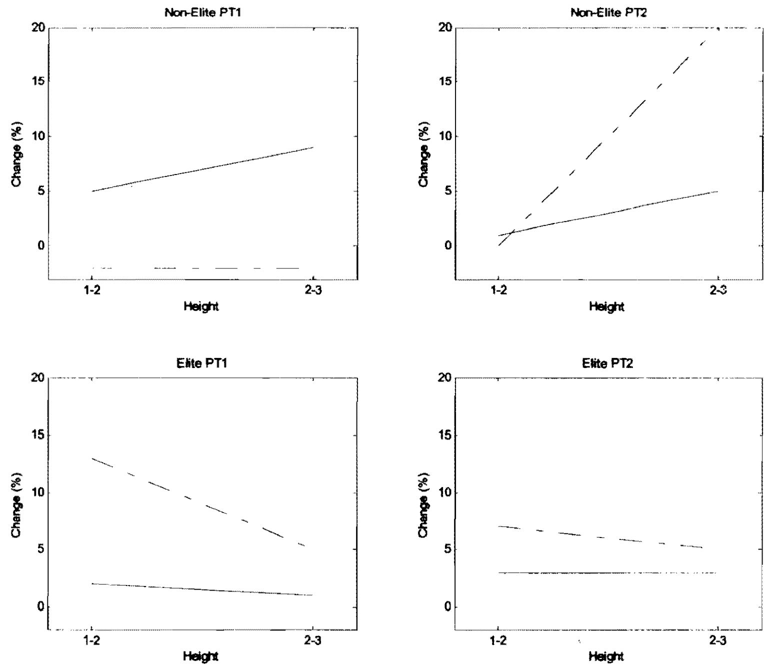
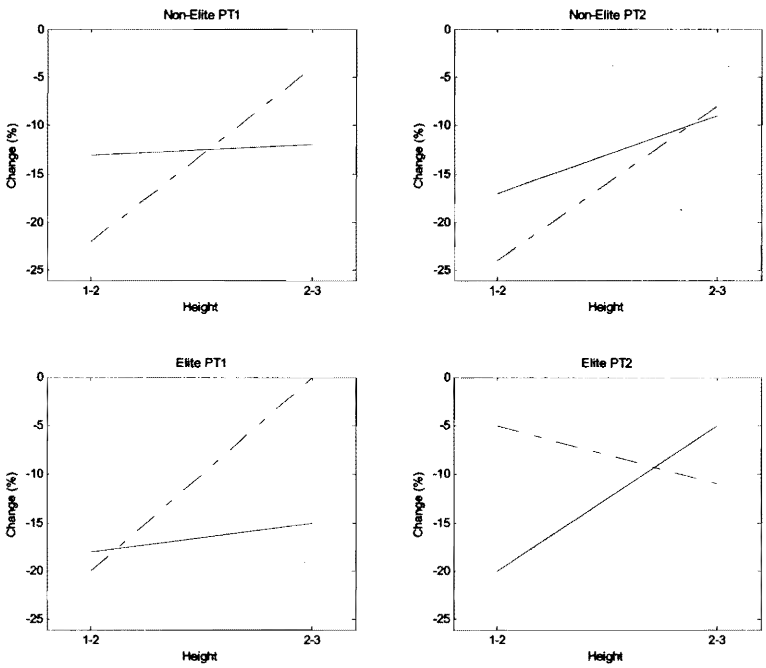


Figure 1. Mean peak GRF associated with heel touchdown (F2) for non-elite and elite males and females, [a] Significant difference between protocols for non-elite males; [b] Significant difference between protocols for elite males; [c] Significant difference between protocols for non-elite females; [d] Significant difference between protocols for elite females; * Significantly different from protocol 1 for elite athletes ($p<0.05$).



(a)



(b)

Figure 2. Percent change for (a) the peak GRF associated with forefoot touchdown (F1) and (b) F2 from height 1 to height 2 and height 2 to height 3, PT1 = absolute heights, PT2 = %MVJ, — = males and —.— = females.

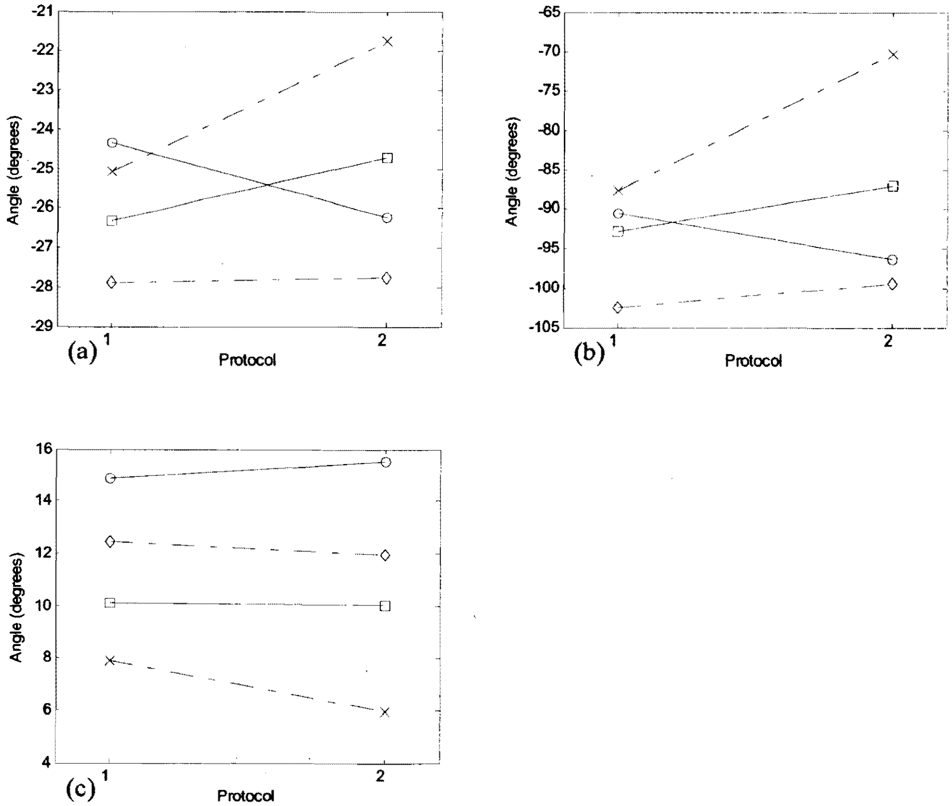


Figure 3. Protocol by Gender interaction for (a) knee flexion contact angle, (b) maximum knee flexion angle and (c) maximum knee adduction angle for —□— = Non-Elite males, —○— = Elite Males, —×— = Non-Elite Females, —◊— Elite Females.

Table 1. Mean knee flexion contact, maximum flexion, maximum adduction angles: means ± standard deviations.

			Knee Contact		Knee Flexion		Knee Adduction	
Group	Protocol	Height	Males[a,b]	Females[c]	Males[a,b]	Females[c,d]	Males	Females[c]
Non Elite	PT1	40	-24.5±4.6	-22.1±4.3	-82.3±10.9	-75.6±13.4	9.7±3.3	6.9±4.2
		60	-26.2±4.7	-25.6±5.3	-91.5±8.1	-88.5±14.4	9.9±3.6	7.4±6.3
		80	-28.3±2.6	-27.5±4.8	-104.8±10.1	-98.7±11.9	10.8±4.7	9.4±5.4
	PT2	70%	-23.7±4.1	-20.4±5.9	-78.5±14.5	-62.6±13.8	9.7±4.6	5.6±4.1
		100%	-23.9±3.2	-22.2±6.2	-87.5±11.8	-71.0±15.2	10.4±3.9	5.8±5.6
		130%	-26.6±2.5	-22.7±5.4	-95.4±8.3	-77.0±15.1	10.0±3.4	6.4±5.1
Elite	PT1	40	-20.2±4.9	-25.6±4.5	-77.4±16.4	-92.3±18.9	14.1±6.2	11.2±6.0
		60	-25.1±4.8	-27.7±6.2	-92.5±13.2	-103.9±15.8	14.8±6.7	12.2±5.5
		80	-27.8±5.7	-30.3±5.8	-101.7±13.1	-111.2±13.7	15.8±7.8	13.9±6.3
	PT2	70%	-24.0±4.4	-27.1±8.2	-86.9±12.5	-92.6±19.7	14.7±7.9	11.2±5.0
		100%	-26.3±4.6	-27.2±6.0	-98.9±13.1	-100.4±12.0	15.5±8.8	11.6±5.7
		130%	-28.3±5.0	-29.1±6.4	-103.4±13.0	-105.2±16.2	16.3±8.3	13.1±5.9

Note: PT1 = absolute heights; PT2 = %MVJ; Joint angles are in degrees; [a] Significant difference between protocols for non-elite males; [b] Significant difference between protocols for elite males; [c] Significant difference between protocols for non-elite females; [d] Significant difference between protocols for elite females; ($p<0.05$).

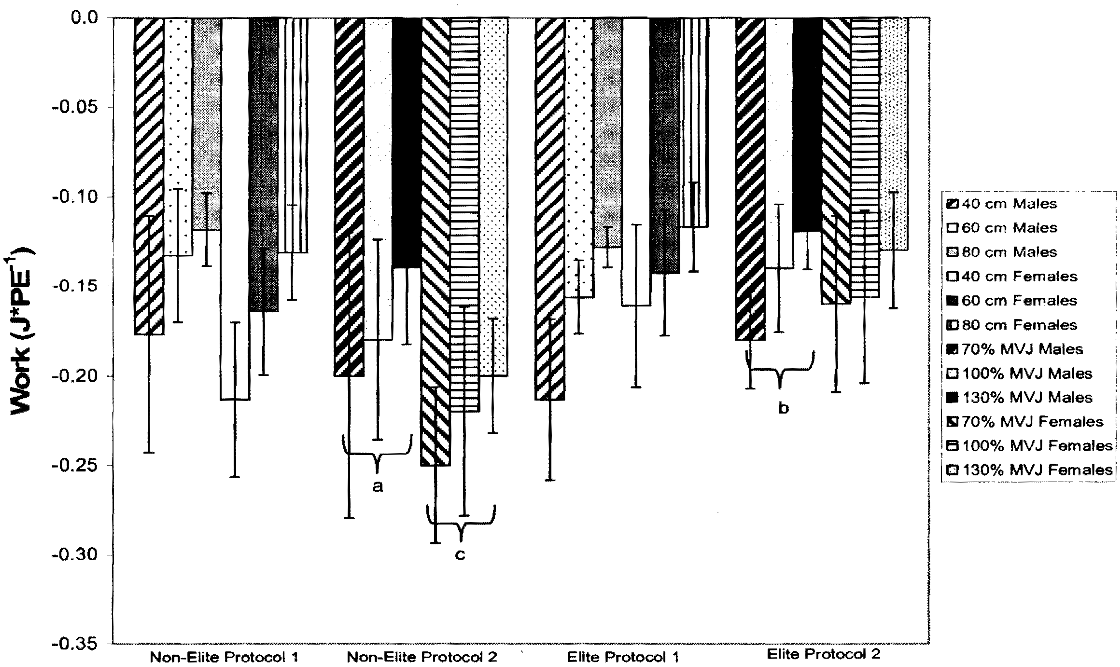
which the follow-up comparison demonstrated a significant decrease from PT1 to PT2 for the non-elite athletes only.

The peak ankle plantarflexion moment increased significantly from PT1 to PT2 for both the non-elite male and female athletes (Table 2). Also a significant decrease from PT1 to PT2 for the elite males for the ankle plantarflexion moment was observed. There was a significant Group × Protocol interaction for the ankle plantarflexion moment and the follow-up comparison revealed that it was significantly smaller in PT2 for the elite athletes (Table 2). The peak knee extension moment increased from PT1 to PT2 for both the elite and non-elite female athletes (Table 2). The comparison for the Group × Protocol interaction showed that the moment was significantly smaller in PT2 for the elite athletes. The relative ankle work increased significantly from PT1 to PT2 for both the non-elite male and female athletes but decreased significantly for the elite male athletes (Figure 4). Only the non-elite females demonstrated a significant decrease from PT1 to PT2 for the relative knee extension work (Figure 4). As the height of landing increased the elite females demonstrated the greatest amount of change from PT1 to PT2 while the elite males demonstrated the least amount of change in the amount of work contributed by the ankle plantarflexors (Figure 5a). The elite females showed the greatest change in the contribution by the knee muscle group to energy absorption (Figure 5b). There was a decreased contribution from the hip muscle group from PT1 to PT2 for all subject groups (Figure 5c).

Table 2. Mean peak ankle plantarflexion and knee extension moments: means ± standard deviations.

Group	Protocol	Height	Ankle Plantarflexion Males[a,b,*]	Ankle Plantarflexion Females[c,*]	Knee Extension Males[*]	Knee Extension Females[c.d,*]
Non Elite	PT1	40	-0.39±0.13	-0.47±0.11	-0.64±0.11	-0.57±0.12
		60	-0.28±0.08	-0.33±0.07	-0.51±0.13	-0.50±0.09
		80	-0.22±0.05	-0.25±0.03	-0.54±0.12	-0.42±0.10
	PT2	70%	-0.44±0.13	-0.69±0.18	-0.72±0.07	-0.72±0.16
		100%	-0.35±0.09	-0.51±0.12	-0.59±0.08	-0.59±0.15
		130%	-0.27±0.08	-0.46±0.10	-0.52±0.09	-0.57±0.12
Elite	PT1	40	-0.47±0.08	-0.36±0.06	-0.56±0.06	-0.49±0.08
		60	-0.32±0.05	-0.28±0.05	-0.46±0.05	-0.40±0.04
		80	-0.25±0.04	-0.23±0.03	-0.46±0.09	-0.39±0.06
	PT2	70%	-0.36±0.05	-0.36±0.08	-0.51±0.07	-0.52±0.10
		100%	-0.28±0.05	-0.31±0.08	-0.47±0.05	-0.45±0.08
		130%	-0.23±0.06	-0.26±0.05	-0.42±0.06	-0.44±0.10

Note: PT1 = absolute heights; PT2 = %MVJ; Peak moment unit is $N\cdot m\cdot J^{-1}$; [a] Significant difference between protocols for non-elite males; [b] Significant difference between protocols for elite males; [c] Significant difference between protocols for non-elite females; [d] Significant difference between protocols for elite females; * Significantly different from protocol 1 for elite athletes ($p<0.05$).



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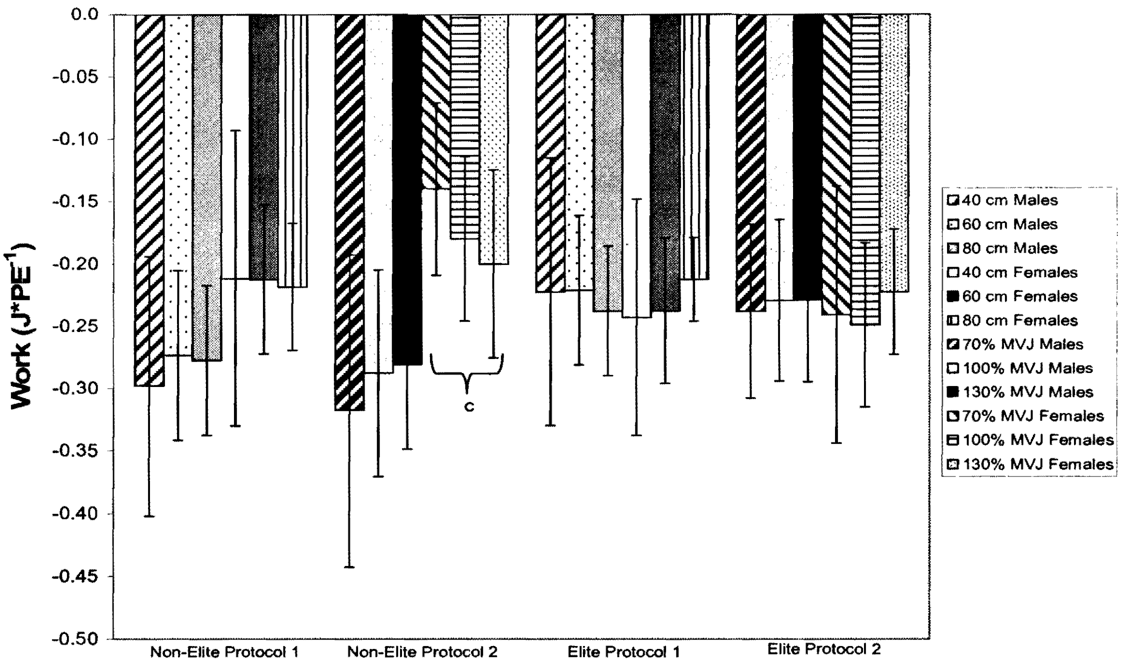

(b)

Figure 4. Relative work for the (a) ankle joint and the (b) knee joint; [a] Significant difference between protocols for non-elite males; [b] Significant difference between protocols for elite males; [c] Significant difference between protocols for non-elite females; [d] Significant difference between protocols for elite females; ($p<0.05$).

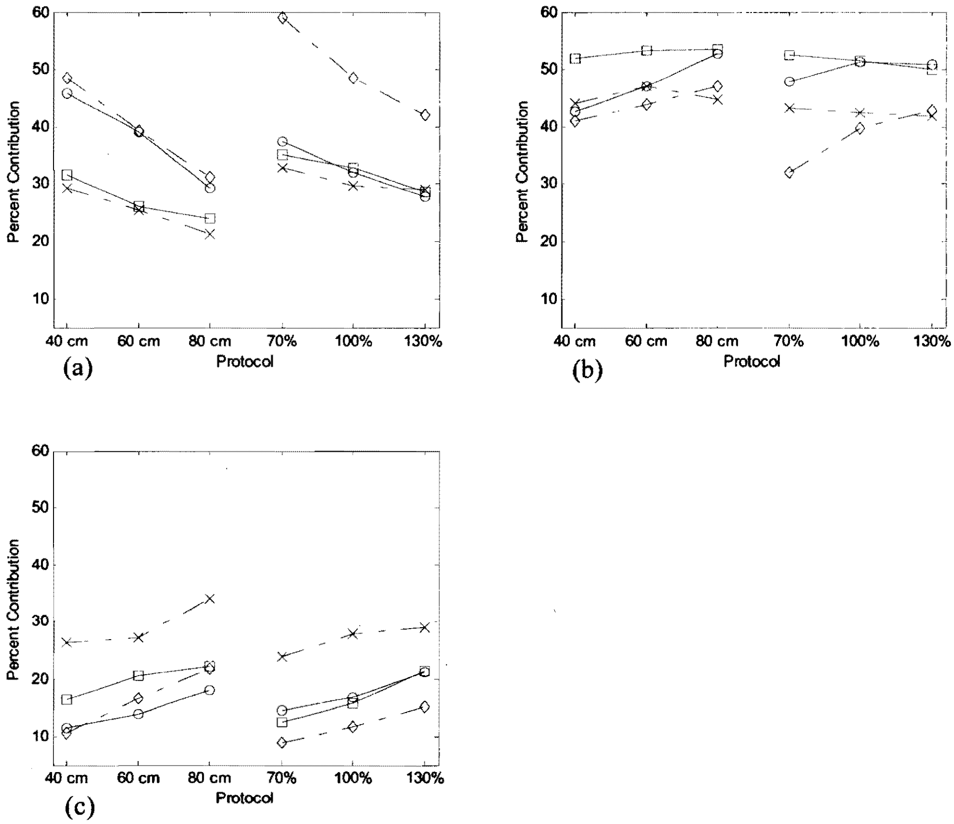

Figure 5. Percent work contributions by the three lower extremity joints: (a) ankle, (b) knee and (c) hip; —□— = Non-Elite males, —○— = Elite Males, —×— = Non-Elite Females, —◊— Elite Females.

Discussion

Based on the past research evidence we hypothesized that female athletes and non-elite athletes would demonstrate less impact attenuation capabilities compared to the male athletes and elite athletes in landing related activities. Our findings support our hypothesis that the non-elite athletes have differing impact attenuation capabilities.

The elite athletes showed significantly smaller second peak GRF force in PT2 compared to the non-elite athletes. Clowers and Zhang (2005) reported that the second GRF peak was significantly smaller for the elite athletes when landing from a protocol based on the subject's MVJ. The authors suggested that the elite athletes may be anticipating the landing and thereby increasing the tension in the lower extremity muscles to aid in the energy absorption at ground contact. Devita and Skelly (1992) and Zhang and colleagues (2000) demonstrated that the first and second GRF peaks respond differently to increased landing heights and that the second GRF peak occurs much later which allows for more of a neuromuscular response from the lower extremity muscles. Further, Zhang and colleagues (2000) showed that the relative increase in the first GRF peak was much larger than the increase for the second GRF peak with increasing landing heights and concluded this may be indicative of a Newtonian/mechanical response without much neuromuscular intervention. Our findings reveal that elite athletes may have more of a neuromuscular response to dissipate the load at landing as evident by the smaller second GRF peak observed compared to the non-elite athletes.

The results from this study also indicated that the mean ankle plantarflexion and knee extension moments were significantly greater for the elite athletes in PT2 compared to non-elite athletes. This suggests that the non-elite athletes and elite athletes have different joint kinetic patterns in absorbing the energy from impact at ground contact. The analysis of the joint moments provides insight into one's ability to control joint motion during landing and thereby dissipate impact loads [14]. Our findings indicate that the elite athletes generate more tension at the ankle plantarflexor and knee extensor muscle groups when landing from the heights in PT2 in order to control the motion of the joint compared to the non-elite group. McNitt-Gray et al. (1993) and Zhang et al. (2000) demonstrated that with increasing landing heights there is increasing amounts of work performed by the lower extremity joints. In the present study and although not statistically significant the percent contributions by the ankle and the knee were generally greater in the elite athletes compared to the non-elite athletes (Figure 5). Conversely, the amount of work contributed by the hip was, even though statistically insignificant, less in the elite athletes compared to the non-elite athletes. This demonstrated that for the elite athletes the ankle joint and knee joint muscle group played larger roles in energy reduction during the different mechanical loading situations where as the hip joint muscle group played a greater role for the non-elite athletes.

Contrary to our original hypothesis, there were no statistical differences between the two genders for any of the variables analyzed. However, we did find evidence that the two genders respond differently in attenuating impact forces during landing. It was stated previously that the first and second GRF peaks respond differently to increased landing heights and that the second GRF peak occurs much later which allows for more of a neuromuscular response from the lower extremity muscles. The average percent increases in the first GRF peak from the lowest height in PT1 were 5.5% to 1.5% for females and 3.5% to 5% for males (Figure 2a). The percent increases in first GRF peak from the lowest height in PT2 were 12.5% to 1.5% for females and 4% to 5% for males. The larger trend in percent increases in the first GRF peak observed for the females indicated that, regardless of training level, females have more of a Newtonian/mechanical response for the first GRF peak compared to the males. Figure 2b depicts the percent increases in the second GRF peak from the lowest height in PT1 which were -21% to -2% for females and -15.5% to -13.5% for males. Also in Figure 2b the percent increases in PT2 for females were -13.5% to -7.5% and -18.5% to -7.5% for males. The smaller trend of changes in the percent change in the second GRF peak observed for males suggests that males may be anticipating the impact force before touchdown and thereby increasing the tension in the lower extremities to help absorb the forces at impact. Furthermore, the trend of greater increases observed for females in the percent change for the first peak GRF and the trend of smaller changes in the second GRF peak for the male athletes suggests different muscle activation patterns between genders may be adopted, which warrants further research.

Studies have shown that changes in landing technique influence the magnitude of the impact forces during landing and that landing with less stiffness (with the knee more flexed) increase the impact force attenuation [16, 44]. Several studies have reported that females land with their knees more extended at contact with both feet [20, 23] and with one foot [21]. In our study, there was a significant Gender × Protocol interaction for the knee contact angle that decreased significantly from PT1 to PT2 for the non-elite males and females, and the elite females while there was a significant increase for the elite males (Table 1 & Figure 3). Hewett et al. (1996) showed that trained females demonstrated increased maximum knee flexion angles after training, which were still similar to untrained males during landings and Decker et al. (2003) reported similar maximum knee flexion angles between male and female recreational athletes when landing from 60 cm. We found no significant gender effect in the maximum knee flexion angle. However, there was a significant decrease for the non-elite athletes and the elite female athletes and a significant increase for the elite males in the maximum knee flexion angle from PT1 to PT2. Additionally a significant decrease was observed from PT1 to PT2 for the non-elite females in the knee adduction angle. These findings illustrate that the subjects of different gender respond differently to the two landing protocols. Specifically, the kinematic changes of the above mentioned variables for the elite males in PT2 is the just opposite compared to the non-elite male and female and elite female athletes. The difference may be explained by the fact that the elite males landed from higher heights in PT2 compared to the other subject groups.

With increasing landing heights there is increasing amounts of work performed by the lower extremity muscle groups (McNitt-Gray et al. (1993) and Zhang et al. (2000)). We found no significant differences between genders for the ankle and knee eccentric work in this study. Decker et al. (2003) reported no differences between genders at each lower extremity joint during landing. However they showed that female recreational athletes had greater energy absorption from the knee and ankle muscle group compared to the hip and that there were no absorption differences between the lower extremity joints for males. In the present study, non-elite males and females had significantly greater eccentric work for the ankle in PT2 compared to PT1 but the elite males showed a significant decrease in the ankle eccentric work from PT1 to PT2 (Figure 4). For the knee joint eccentric work, only the non-elite females showed a significant decrease from

PT1 to PT2. These findings demonstrate that male and female athletes may possess different joint kinetic patterns to dissipate the impact loads which may be a result of different conditioning backgrounds. Specifically, the elite females showed no significant increase or decrease from one protocol to another in the ankle or knee eccentric work. On the other hand, elite male athletes used significantly less ankle work in PT2. Yet, the non-elite males and females and showed significant changes from one protocol to the other in the ankle eccentric work. This suggests that elite female athletes do not alter their joint kinetic patterns to attenuate the impact forces but elite male athletes adjust joint kinetic patterns to the different mechanical loading situations. This finding may be a result of why females have a greater potential for injury, which requires further research.

The findings in the present study demonstrated differences between the non-elite and elite athletes in their ability in impact attenuation during landing. It was confirmed that elite athletes had more of a neuromuscular response and different joint kinetic patterns. Statistically significant evidence supporting the hypothesis that there are gender differences within the selected kinematic, kinetic and GRF variables was not discovered in the present study. However, it was realized through the examination of the percent changes in the vertical GRF that females landed with a trend of greater vertical GRF peak values compared to their male counterparts. In addition, the results demonstrated that elite males had a different knee joint kinematic response when landing from the heights in PT2 to absorb the energy from impact. Further, evidence was presented suggesting that the elite male athletes adjust their joint kinetic patterns to different loading conditions and that the elite female athletes do not alter their joint kinetic patterns.

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References

1. Ferretti, A., et al., *Knee ligament injuries in volleyball players.* Am J Sports Med, 1992. **20**(2): p. 203-7.
2. Gray, J., et al., *A survey of injuries to the anterior cruciate ligament of the knee in female basketball players.* Int J Sports Med, 1985. **6**(6): p. 314-6.
3. Hewett, T.E., et al., *The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study.* Am J Sports Med, 1999. **27**(6): p. 699-706.
4. Arendt, E. and R. Dick, *Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature.* Am J Sports Med, 1995. **23**(6): p. 694-701.
5. Huston, L.J. and E.M. Wojtys, *Neuromuscular performance characteristics in elite female athletes.* Am J Sports Med, 1996. **24**(4): p. 427-36.
6. Kreighbaum, E. and K.M. Barthels, *Performance Analysis of Pushlike Movements*, in *Biomechanics: A Qualitative Approach for Studying Human Movement.* 1996, Allyn and Bacon: Boston. p. 619.
7. Dowling, J.J. and L. Vamos, *Identification of Kinetic and Temporal Factors Related to Vertical Jump Performance.* Journal of Applied Biomechanics, 1993. **9**(2): p. 95-110.
8. McBride, J.M., et al., *The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed.* J Strength Cond Res, 2002. **16**(1): p. 75-82.
9. Stone, M.H., et al., *Power and maximum strength relationships during performance of dynamic and static weighted jumps.* J Strength Cond Res, 2003. **17**(1): p. 140-7.
10. Fatouros, I.G.J., A.Z.; Leontsini, D.; and K.A. Taxildaris, N.; Kostopoulos, N.; Buckenmeyer, P., *Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength.* Journal of strength and conditioning research, 2000. **14**(4): p. 470-476.
11. Luebbers, P.E., et al., *Effects of plyometric training and recovery on vertical jump performance and anaerobic power.* J Strength Cond Res, 2003. **17**(4): p. 704-9.
12. Dufek, J.S. and B.T. Bates, *The evaluation and prediction of impact forces during landings.* Med Sci Sports Exerc, 1990. **22**(3): p. 370-7.
13. Gross, T.S. and R.C. Nelson, *The shock attenuation role of the ankle during landing from a vertical jump.* Med Sci Sports Exerc, 1988. **20**(5): p. 506-14.
14. McNitt-Gray, J.L., *Kinetics of the lower extremities during drop landings from three heights.* J Biomech, 1993. **26**(9): p. 1037-46.
15. Self, B.P. and D. Paine, *Ankle Biomechanics During Four Landing Techniques.* Medicine & Science in Sports & Exercise, 2001. **33**(8): p. 1338-1344.
16. Zhang, S., B.T. Bates, and J.S. Dufek, *Contributions of Lower Extremity Joints to Energy Dissipation During Landings.* Medicine and Science in Sports and Exercise, 2000. **32**(4): p. 812-819.

17. Arampatzis, A., G.P. Bruggemann, and G.M. Klapsing, *A three-dimensional shank-foot model to determine the foot motion during landings.* Med Sci Sports Exerc, 2002. **34**(1): p. 130-8.
18. Hass, C.J., et al., *Lower Extremity Biomechanics Differ in Prepubescent and Postpubescent Female Athletes During Stride Jump Landings.* Journal of Applied Biomechanics, 2003. **19**: p. 139-152.
19. Chappell, J.D., et al., *A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks.* Am J Sports Med, 2002. **30**(2): p. 261-7.
20. Decker, M.J., et al., *Gender differences in lower extremity kinematics, kinetics and energy absorption during landing.* Clin Biomech (Bristol, Avon), 2003. **18**(7): p. 662-9.
21. Lephart, S.M., et al., *Gender differences in strength and lower extremity kinematics during landing.* Clin Orthop, 2002(401): p. 162-9.
22. Hewett, T.E., et al., *Plyometric Training in Female Athletes Decreased Impact Forces and Increased Hamstring Torques.* The American Journal of Sports Medicine, 1996. **24**(6): p. 765-773.
23. Huston, L.J., et al., *Gender differences in knee angle when landing from a drop-jump.* Am J Knee Surg, 2001. **14**(4): p. 215-9; discussion 219-20.
24. Fagenbaum, R. and W.G. Darling, *Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury.* Am J Sports Med, 2003. **31**(2): p. 233-40.
25. Ford, K.R., G.D. Myer, and T.E. Hewett, *Valgus knee motion during landing in high school female and male basketball players.* Med Sci Sports Exerc, 2003. **35**(10): p. 1745-50.
26. Hoffman, J.R., D. Liebermann, and A. Gusis, *Relationship of leg strength and power to ground reaction forces in both experienced and novice jump trained personnel.* Aviat Space Environ Med, 1997. **68**(8): p. 710-4.
27. Hunter, J.P. and R.N. Marshall, *Effects of power and flexibility training on vertical jump technique.* Med Sci Sports Exerc, 2002. **34**(3): p. 478-86.
28. James, C.R., J.S. Dufek, and B.T. Bates, *Effects of injury proneness and task difficulty on joint kinetic variability.* Med Sci Sports Exerc, 2000. **32**(11): p. 1833-44.
29. Ross, S.E. and K.M. Guskiewicz, *Examination of Static and Dynamic Postural Stability in Individuals With Functionally Stable and Unstable Ankles.* Clin J Sport Med, 2004. **14**(6): p. 332-338.
30. Manal, K., et al., *Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study.* Gait Posture, 2000. **11**(1): p. 38-45.
31. McClay, I. and K. Manal, *Three-dimensional kinetic analysis of running: significance of secondary planes of motion.* Med Sci Sports Exerc, 1999. **31**(11): p. 1629-37.
32. Seidel, G.K., et al., *Hip joint center location from palpable bony landmarks--a cadaver study.* J Biomech, 1995. **28**(8): p. 995-8.
33. Garhammer, J., *Weight Lifting and Training*, in *Biomechanics of Sport*, C.L. Vaughan, Editor. 1989, CRC Press: Boca Raton. p. 169-212.

34. Baechle, T.R. and R.W. Earle, *The Biomechanics of Resistance Exercise*, in *Essentials of Strength Training and Conditioning*. 2000, Human Kinetics: Champaign, IL. p. 25-56.
35. Driss, T., et al., *Effects of external loading on power output in a squat jump on a force platform: a comparison between strength and power athletes and sedentary individuals.* J Sports Sci, 2001. **19**(2): p. 99-105.
36. Radin, E.L. and I.L. Paul, *Response of joints to impact loading. I. In vitro wear.* Arthritis Rheum, 1971. **14**(3): p. 356-62.
37. Hass, C.J., et al., *Knee biomechanics during landings: comparison of pre- and postpubescent females.* Med Sci Sports Exerc, 2005. **37**(1): p. 100-7.
38. Zhang, S., K. Clowers, and C. Kohstall, *Impact Attenuation and Kinetic Characteristics of Training Shoes in Landing and Jumping Activities*, in *2005 Annual Conference of American College of Sports Medicine*. 2005: Nashville, TN.
39. Kadaba, M.P., H.K. Ramakrishnan, and M.E. Wootten, *Measurement of Lower-Extremity Kinematics During Level Walking.* Journal of Orthopaedic Research, 1990. **8**(3): p. 383-392.
40. Karlsson, D. and R. Tranberg, *On skin movement artefact-resonant frequencies of skin markders attached to the leg.* Human Movement Science, 1999. **18**: p. 627-625.
41. Reinschmidt, C., et al., *Effect of skin movement on the analysis of skeletal knee joint motion during running.* J Biomech, 1997. **30**(7): p. 729-32.
42. Grood, E.S. and W.J. Suntay, *A joint coordinate system for the clinical description of three-dimensional motions: application to the knee.* J Biomech Eng, 1983. **105**(2): p. 136-44.
43. Vaughan, C.L., *Dynamics of Human Gait.* 2nd ed. 1999, Cape Town: Kiboho Publishers. 141.
44. Devita, P. and W.A. Skelly, *Effect of landing stiffness on joint kinetics and energetics in the lower extremity.* Med Sci Sports Exerc, 1992. **24**(1): p. 108-15.
45. Agel, J., E.A. Arendt, and B. Bershadsky, *Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review.* Am J Sports Med, 2005. **33**(4): p. 524-30.
46. Clowers, K. and S. Zhang, *Effects of Power Generation on Lower Extremity Landing Biomechanics.* 2005, Unpublished Dissertation. p. 22.

Appendices

Appendix A

Abbreviations

Abbreviations

Abd	Abduction
Add	Adduction
BF	Breaking Force
Cond	Condition
Cont	Contact
DF	Dorsiflexion
EF	Elite Females
EM	Elite Males
Ext	Extension
Ext Rotat	External Rotation
F1	1st Vertical Ground Reaction Force Peak
F2	2nd Vertical Ground Reaction Force Peak
Flex	Flexion
Grp	Group
H	Height
Int	Internal
LRate1	Loading Rate for F1
LRate2	Loading Rate for F2
NEF	Non-elite females
NEM	Non-elite males
Plant Flex	Plantarflexion
Prot	Protocol
ROM	Range of Motion
Rotat	Rotation
Subj	Subject
T BF	Time to BF
T F1	Time to F1
T F2	Time to F2
TI	Total Impulse

Appendix B

Descriptive Characteristics and Landing Heights of Male Athletes

Descriptive characteristics and landing heights for male subjects.

Subject	Group	Age	Height (m)	Weight (kg)	Landing Height for Protocol 2 (mm)		
					70%	100%	130%
2	Non-elite	27	1.83	67.27	36.33	51.90	67.47
7	Non-elite	23	1.87	86.82	34.84	49.77	64.70
9	Non-elite	29	1.84	76.48	37.40	53.43	69.46
11	Non-elite	23	1.80	82.27	35.79	51.13	66.47
18	Non-elite	25	1.77	66.59	30.59	43.70	56.81
24	Non-elite	21	1.82	78.64	30.17	43.10	56.03
27	Non-elite	23	1.77	79.55	26.74	38.20	49.66
28	Non-elite	21	1.85	89.09	33.76	48.23	62.70
22	Elite	24	1.82	74.66	48.95	69.93	90.91
25	Elite	22	1.89	87.27	44.89	64.13	83.37
26	Elite	22	1.74	77.27	46.02	65.74	85.46
29	Elite	23	1.88	79.55	51.73	73.90	86.00
31	Elite	23	1.84	81.82	51.78	73.97	96.16
32	Elite	23	1.94	95.00	55.30	79.00	83.00
33	Elite	19	1.84	83.64	50.17	71.67	93.17
35	Elite	22	1.87	112.27	44.92	64.17	83.42
Mean Non-elite		24.00	1.82	78.34	33.20	47.43	61.66
SD Non-elite		2.83	0.04	8.18	3.68	5.26	6.84
Mean Elite		22.25	1.85	86.43	49.22	70.31	87.69
SD Elite		1.49	0.06	12.19	3.75	5.35	5.05
Mean		23.13	1.83	82.39	41.21	58.87	74.67
SD		2.36	0.05	10.87	9.02	12.88	14.64

Note: SD = standard deviation

Appendix C

Descriptive Characteristics and Landing Heights of Female Athletes

Descriptive characteristics and landing heights for female subjects.

					Landing Height for Protocol 2 (mm)		
Subject	Group	Age	Height (m)	Weight (kg)	70%	100%	130%
2	Non-elite	23	1.66	46.82	20.11	28.73	37.35
3	Non-elite	30	1.62	59.09	25.83	36.90	47.97
6	Non-elite	21	1.68	50.45	17.20	24.57	31.94
16	Non-elite	22	1.68	68.86	21.93	31.33	40.73
20	Non-elite	19	1.64	64.09	24.15	34.50	44.85
21	Non-elite	21	1.71	58.86	21.82	31.17	40.52
22	Non-elite	22	1.66	65.23	25.34	36.20	47.06
25	Non-elite	23	1.72	58.86	23.57	33.67	43.77
1	Elite	22	1.72	59.09	42.61	60.87	79.13
4	Elite	23	1.69	67.38	33.04	47.20	61.36
7	Elite	23	1.63	63.41	34.77	49.67	64.57
8	Elite	21	1.57	51.36	38.59	55.13	71.67
9	Elite	22	1.63	58.18	41.56	59.37	77.18
10	Elite	26	1.68	67.05	36.84	52.63	68.42
11	Elite	18	1.61	60.45	34.28	48.97	63.66
26	Elite	23	1.73	64.09	32.60	46.57	60.54
Mean Non-elite		22.63	1.67	59.03	22.49	32.13	41.77
SD Non-elite		3.25	0.03	7.40	2.87	4.10	5.33
Mean Elite		22.25	1.66	61.38	36.79	52.55	68.32
SD Elite		1.99	0.05	4.77	6.90	9.86	12.82
Mean		22.44	1.66	60.21	29.64	42.34	55.04
SD		2.71	0.04	6.33	8.07	11.53	14.98

Note: SD = standard deviation

Appendix D

Mean Residuals from Camera Calibration for Both Male and Female Subjects

Mean calibration residuals for both males and females.

Males		Females	
Subject #	mm	Subject #	mm
2	0.740	1	0.911
7	0.749	2	0.990
9	0.815	3	0.877
11	0.747	4	0.963
18	0.735	6	0.955
22	0.773	7	0.942
24	0.943	8	0.884
25	1.019	9	0.911
26	1.017	10	0.990
27	0.944	11	0.981
28	0.944	16	0.938
29	1.004	20	0.984
31	0.910	21	1.055
32	0.968	22	0.984
33	0.977	25	0.998
35	0.957	26	0.884
Mean	0.890		0.953
Standard Deviation	0.109		0.050

Appendix E

Group Table Right Ankle Angle Data for Part III

Contact, peak angles, and ROM for the ankle joint for Part III.

Group	Protocol	H	Cont	DF	DF ROM	Abd	Abd ROM	Ext Rotat	Ext Rotat ROM
Non Elite	1	40	-11.9 (8.3)	33.5 (5.5)	45.5 (8.5)	-1.0 (3.5)	-7.4 (4.4)	-97.1 (8.2)	-6.5 (2.5)
		60	-12.8 (5.4)	33.8 (4.1)	46.4 (5.6)	-0.6 (2.2)	-7.1 (4.9)	-97.4 (6.1)	-6.4 (2.8)
		80	-14.9 (3.7)	35.2 (4.4)	50.0 (5.1)	-2.2 (3.0)	-9.0 (5.3)	-99.0 (6.0)	-8.2 (3.2)
	2	70%	-13.0 (6.6)	33.4 (5.8)	46.2 (7.8)	-0.5 (3.2)	-6.6 (4.2)	-96.6 (6.2)	-6.1 (1.3)
		100%	-13.5 (6.1)	34.6 (5.2)	47.4 (7.5)	-1.4 (3.3)	-8.4 (4.9)	-97.9 (7.2)	-7.3 (2.3)
		130%	-14.1 (5.1)	33.9 (4.0)	47.9 (6.8)	-1.6 (3.0)	-7.8 (4.9)	-97.1 (7.2)	-8.6 (7.3)
Elite	1	40	-16.7 (6.5)	32.5 (3.6)	49.1 (5.8)	-3.7 (4.9)	-10.4 (6.5)	-101.9 (8.9)	-9.8 (3.9)
		60	-16.2 (5.9)	34.7 (3.6)	50.1 (7.2)	-5.9 (4.4)	-13.1 (6.9)	-103.6 (6.3)	-12.9 (7.6)
		80	-15.9 (4.8)	34.0 (4.2)	49.4 (6.3)	-6.4 (4.0)	-13.5 (5.4)	-104.0 (7.5)	-9.2 (4.9)
	2	70%	-16.2 (5.5)	34.4 (3.1)	50.0 (6.6)	-4.44[a] (4.8)	-11.5 (5.9)	-102.3 (6.4)	-8.1 (4.1)
		100%	-15.7 (6.3)	36.0 (4.2)	49.8 (8.2)	-7.21[a] (3.3)	-12.3 (4.9)	-104.5 (6.7)	-9.3 (5.7)
		130%	-14.2 (5.7)	33.6 (4.9)	47.5 (9.1)	-7.34[a] (4.3)	-12.6 (6.2)	-104.3 (6.4)	-9.6 (5.1)

Note: Angle units are degrees; values in parenthesis are standard deviation; * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix F

Group Table Right Ankle Angular Velocity for Part III

Contact and peak velocities for the ankle joint for Part III.

Group	Protocol	Height	Contact	Dorsi-Flexion	Abduction	External Rotation
Non Elite	1	40	455.73	758.95	-172.12	-98.61
			(86.64)	(120.85)	(84.88)	(50.80)
		60	567.48	872.91	-182.24	-107.09
			(61.67)	(109.54)	(53.39)	(74.25)
		80	607.32	965.27	-236.38	-119.94
			(117.39)	(59.88)	(78.87)	(65.60)
	2	70%	412.93[a]	743.32	-166.91	-95.68
			(76.66)	(106.27)	(46.11)	(45.09)
		100%	512.84[a]	834.86	-190.31	-112.09
			(116.80)	(116.39)	(56.11)	(54.06)
		130%	545.64[a]	879.63	-202.0	-110.55
			(118.08)	(97.71)	(68.36)	(51.59)
Elite	1	40	442.77	798.70	-260.43	-145.55
			(56.99)	(117.20)	(93.84)	(91.97)
		60	555.13	950.03	-300.55	-193.25
			(71.78)	(89.63)	(177.14)	(121.55)
		80	615.68	954.21	-285.12	-148.41
			(81.42)	(141.71)	(179.13)	(132.72)
	2	70%	492.33	864.28	-249.13	-134.20
			(56.50)	(106.30)	(127.61)	(56.83)
		100%	638.15	974.08	-269.05	-203.58
			(116.14)	(156.63)	(158.0)	(142.90)
		130%	606.27	917.34	-262.53	-154.33
			(95.01)	(151.79)	(148.46)	(124.21)

Note: Angular velocity units are degrees•s^{-1}; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix G

Group Table Right Knee Angle for Part III

Contact, peak angles, and ROM for the knee joint for Part III.

Group	Protocol	Height	Contact	Flexion	Flexion ROM	Add	Add ROM	Int Rotat	Int Rotat ROM
Non Elite	1	40	-24.53	-82.32	57.79	9.70	4.70	1.05	9.46
			(4.60)	(10.91)	(9.47)	(3.34)	(4.58)	(5.66)	(5.47)
		60	-26.17	-91.55	65.41	9.87	4.92	3.19	6.05
			(4.66)	(8.05)	(9.33)	(3.58)	(4.74)	(4.10)	(10.13)
		80	-28.33	-104.75	76.48	10.79	6.18	5.11	12.44
			(2.56)	(10.10)	(10.72)	(4.73)	(5.10)	(6.78)	(5.95)
	2	70%	-23.66	-78.48[a]	54.80[a]	9.65	4.89	0.39[a]	9.13
			(4.12)	(14.51)	(12.08)	(4.57)	(5.56)	(5.88)	(4.55)
		100%	-23.93	-87.50[a]	63.59[a]	10.44	5.52	1.16[a]	10.87
			(3.19)	(11.83)	(10.57)	(3.88)	(5.49)	(6.45)	(5.45)
		130%	-26.57	-95.42[a]	68.84[a]	10.03	5.63	3.54[a]	10.38
			(2.54)	(8.25)	(8.71)	(3.35)	(4.79)	(5.40)	(4.74)
Elite	1	40	-20.20	-77.43	57.19	14.11	5.72	7.91	16.65
			(4.94)	(16.44)	(14.41)	(6.22)	(4.36)	(8.07)	(5.89)
		60	-25.06	-92.51	67.44	14.75	5.44	12.12	19.19
			(4.78)	(13.23)	(13.61)	(6.74)	(6.25)	(7.16)	(6.40)
		80	-27.77	-101.72	74.13	15.79	6.18	15.33	20.57
			(5.71)	(13.08)	(13.71)	(7.76)	(6.74)	(6.98)	(7.84)
	2	70%	-24.02	-86.87[a]	62.82	14.71	5.99	10.44	18.64
			(4.43)	(12.49)	(14.24)	(7.89)	(6.47)	(6.98)	(6.18)
		100%	-26.34	-98.94[a]	71.55	15.54	5.73	15.54	20.88
			(4.63)	(13.08)	(14.71)	(8.78)	(7.02)	(8.47)	(8.36)
		130%	-28.33	-103.36[a]	72.52	16.33	6.37	15.86	21.11
			(4.95)	(13.01)	(11.43)	(8.34)	(7.13)	(8.17)	(8.41)

Angle units are degrees; values in parenthesis are standard deviation; * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix H

Group Table Right Knee Angular Velocity for Part III

Contact and peak angular velocities for the knee joint for Part III

Group	Protocol	Height	Contact	Flexion	Adduction	Internal Rotation
Non Elite	1	40	-270.0 (49.37)	-509.24 (50.64)	100.51 (27.98)	131.97 (27.94)
		60	-309.05 (30.38)	-596.39 (49.18)	142.96 (58.50)	134.05 (41.25)
		80	-355.75 (57.27)	-700.79 (38.96)	171.07 (55.92)	133.95 (68.44)
	2	70%	-241.52[a] (42.17)	-466.96[a] (48.57)	97.52 (43.90)	127.37 (33.68)
		100%	-294.64[a] (36.09)	-554.72[a] (56.24)	115.20 (43.89)	141.61 (48.98)
		130%	-329.40[a] (51.91)	-623.46[a] (67.66)	145.75 (37.64)	113.06 (52.79)
Elite	1	40	-282.59 (67.58)	-498.05 (52.24)	142.49 (56.52)	138.07 (61.93)
		60	-348.42 (62.79)	-564.95 (19.28)	173.06 (80.40)	149.70 (98.92)
		80	-385.96 (61.93)	-631.44 (46.34)	187.62 (91.92)	119.86 (95.29)
	2	70%	-315.78 (57.69)	-532.25[a] (46.47)	145.69 (69.02)	127.02 (56.14)
		100%	-375.94 (53.88)	-607.75[a] (22.71)	182.83 (100.74)	146.39 (92.59)
		130%	-392.24 (90.96)	-646.27[a] (49.57)	199.26 (89.10)	144.65 (83.45)

Note: Angular velocity units are degrees•s^{-1}; values in parenthesis are standard deviation; * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix I

Group Table Right Hip Angle for Part III

Contact, peak angles, and ROM for the hip joint for Part III.

Group	Protocol	Height	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Int Rotat	Int Rotat ROM
Non Elite	1	40	18.78 (5.60)	59.44 (16.08)	41.14 (14.37)	-10.74 (6.16)	-0.95 (4.49)	5.19 (2.22)	4.05 (1.96)
		60	23.21 (5.99)	74.96 (13.72)	49.40 (9.77)	-10.90 (6.48)	-2.22 (5.46)	12.05 (19.84)	14.05 (33.20)
		80	27.36 (5.79)	94.54 (13.80)	62.52 (11.44)	-12.15 (5.95)	-1.38 (5.13)	10.90 (8.76)	9.80 (6.65)
	2	70%	17.03[a] (4.73)	52.80[a] (16.05)	36.0 (14.31)	-9.48 (6.19)	-1.03 (3.36)	4.50 (3.41)	2.57 (1.50)
		100%	19.19[a] (6.61)	64.30[a] (18.86)	43.01 (13.99)	-10.73 (5.97)	-1.61 (5.60)	5.32 (4.07)	5.13 (5.47)
		130%	24.15[a] (4.55)	80.15[a] (9.97)	56.03 (10.39)	-10.84 (5.50)	-1.15 (4.26)	6.58 (4.65)	5.71 (5.60)
Elite	1	40	17.28 (8.59)	52.40 (23.07)	35.11 (19.99)	-12.19 (8.16)	-3.89 (6.60)	8.74 (9.04)	4.91 (3.61)
		60	23.53 (8.84)	67.51 (22.27)	43.98 (18.73)	-14.77 (10.55)	-5.03 (6.94)	10.17 (10.28)	7.71 (7.28)
		80	25.91 (8.50)	82.12 (20.04)	56.21 (17.51)	-16.61 (11.46)	-6.73 (8.02)	9.08 (8.91)	9.07 (9.09)
	2	70%	21.50[a] (8.04)	62.01[a] (21.06)	40.51 (19.53)	-12.69 (11.58)	-4.41 (7.07)	8.69 (11.27)	6.49 (6.04)
		100%	24.07[a] (9.43)	75.46[a] (22.0)	51.63 (20.11)	-15.42 (13.18)	-5.47 (8.61)	11.26 (9.62)	8.67 (8.16)
		130%	27.23[a] (10.11)	85.82[a] (23.13)	56.51 (17.66)	-16.55 (8.76)	-5.51 (6.81)	9.51 (7.13)	8.20 (9.46)

Note: Angle units are degrees; values in parenthesis are standard deviation; * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix J

Group Table Right Hip Angular Velocity for Part III

Contact and peak angular velocities for the hip joint for Part III

Group	Protocol	Height	Contact	Flexion	Abduction	Internal Rotation
Non Elite	1	40	137.70 (34.49)	365.45 (83.18)	-84.78 (13.43)	144.86 (46.70)
		60	156.41 (42.71)	444.87 (57.20)	-152.04 (86.64)	175.26 (52.39)
		80	197.34 (38.45)	541.49 (31.16)	-147.40 (37.88)	166.61 (30.83)
	2	70%	114.77[a] (37.86)	316.17[a] (73.90)	-81.72[a] (19.93)	152.28 (30.59)
		100%	143.50[a] (37.05)	404.35[a] (84.04)	-93.46[a] (22.59)	158.44 (39.40)
		130%	171.25[a] (45.97)	471.68[a] (60.14)	-113.63[a] (27.38)	155.72 (26.22)
Elite	1	40	133.73 (77.57)	299.17 (92.26)	-97.42 (64.29)	119.95 (48.33)
		60	160.94 (73.07)	357.73 (61.10)	-130.0 (75.45)	133.57 (64.85)
		80	184.80 (85.53)	440.10 (66.66)	-130.74 (57.30)	130.12 (51.33)
	2	70%	148.52 (73.83)	332.80 (75.80)	-108.25 (58.24)	128.94 (73.15)
		100%	180.95 (68.98)	386.06 (80.21)	-129.17 (53.81)	131.74 (59.01)
		130%	195.62 (86.43)	444.61 (60.64)	-136.70 (61.90)	140.77 (55.80)

Note: Angular velocity units are degrees•s^{-1}; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix K

Group Table GRF Data for Part III

GRF Force variables for Part III.

Grp	PT	H	BF	T BF	F1	T F1	F2	T F2	LRate1	LRate2	TI
Non Elite	1	40	-1.34	0.01	2.68	0.01	6.09	0.06	369.72	132.83	1.01
			(0.33)	(0.0)	(0.58)	(0.01)	(1.12)	(0.01)	(155.53)	(49.13)	(0.11)
		60	-1.47	0.01	2.81	0.01	5.29	0.05	377.25	140.43	0.75
			(0.33)	(0.0)	(0.53)	(0.0)	(0.39)	(0.01)	(143.17)	(31.52)	(0.05)
		80	-1.45	0.01	3.07	0.01	4.67	0.04	446.84	142.66	0.59
			(0.22)	(0.0)	(0.32)	(0.0)	(0.60)	(0.0)	(145.57)	(36.94)	(0.04)
	2	70%	-1.34	0.02	2.73	0.01	6.99	0.061[a]	294.26	135.41	1.23[a]
			(0.35)	(0.01)	(0.60)	(0.0)	(1.67)	(0.01)	(148.90)	(54.87)	(0.14)
		100%	-1.37	0.01	2.75	0.01	5.78	0.053[a]	429.01	127.93	0.95[a]
			(0.30)	(0.0)	(0.35)	(0.0)	(0.91)	(0.01)	(231.24)	(42.90)	(0.14)
		130%	-1.46	0.01	2.90	0.01	5.27	0.047[a]	399.25	126.97	0.74[a]
			(0.41)	(0.0)	(0.53)	(0.0)	(0.54)	(0.01)	(160.05)	(47.03)	(0.11)
Elite	1	40	-1.26	0.01	2.81	0.01	5.39	0.07	296.87	91.11*	0.99
			(0.22)	(0.0)	(0.62)	(0.0)	(0.94)	(0.01)	(66.38)	(31.50)	(0.05)
		60	-1.20	0.01	2.87	0.01	4.40	0.06	326.19	90.75*	0.73
			(0.15)	(0.0)	(0.48)	(0.0)	(0.86)	(0.01)	(64.65)	(31.88)	(0.01)
		80	-1.19	0.01	2.90	0.01	3.74	0.05	381.49	91.8*	0.58
			(0.25)	(0.0)	(0.64)	(0.0)	(0.95)	(0.01)	(132.51)	(48.59)	(0.03)
	2	70%	-1.19	0.01	2.71	0.01	4.75[a]	0.060[a]	285.87	90.49*	0.84[a]
			(0.18)	(0.0)	(0.54)	(0.0)	(1.33)	(0.01)	(82.01)	(47.83)	(0.08)
		100%	-1.17	0.01	2.81	0.01	3.82[a]	0.053[a]	327.39	81.06*	0.65[a]
			(0.16)	(0.0)	(0.51)	(0.0)	(1.01)	(0.01)	(83.56)	(40.51)	(0.05)
		130%	-1.27	0.01	2.89	0.01	3.63[a]	0.047[a]	431.27	99.02*	0.52[a]
			(0.31)	(0.01)	(0.75)	(0.0)	(0.97)	(0.01)	(179.01)	(45.01)	(0.05)

Note: Force units are $N \cdot J^{-1}$; Loading Rate units is $N \cdot J^{-1} \cdot s^{-1}$;values in parenthesis are standard deviation; see text for full description of variables; Significant, $p<0.05$, * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix L

Group Table Right Normalized Ankle Moment for Part III

Peak plantar flexion, adduction, and external rotation moments for the ankle joint for Part III.

Group	Protocol	Height	Plantar Flexion	Adduction	Internal Rotation
Non Elite	1	40	-0.39 (0.13)	-0.01 (0.02)	0.03 (0.03)
		60	-0.28 (0.08)	-0.02 (0.01)	0.02 (0.01)
		80	-0.22 (0.05)	-0.01 (0.02)	0.02 (0.01)
	2	70%	-0.44[a] (0.13)	-0.01 (0.03)	0.02 (0.02)
		100%	-0.35[a] (0.09)	-0.01 (0.01)	0.02 (0.02)
		130%	-0.27[a] (0.08)	-0.01 (0.02)	0.02 (0.02)
Elite	1	40	-0.47 (0.08)	-0.02 (0.02)	0.01 (0.01)
		60	-0.32 (0.05)	-0.02 (0.03)	0.01 (0.01)
		80	-0.25 (0.04)	-0.01 (0.02)	0.0 (0.01)
	2	70%	-0.36[a] (0.05)	-0.02 (0.01)	0.01 (0.01)
		100%	-0.28[a] (0.05)	-0.02 (0.02)	0.01 (0.01)
		130%	-0.23[a] (0.06)	-0.01 (0.02)	0.01 (0.01)

Note: Peak moment unit is $N\bullet m\bullet J^{-1}$; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix M

Group Table Right Normalized Knee Moment for Part III

Peak extension, adduction, and internal rotation moments for the knee joint for Part III.

Group	Protocol	Height	Extension	Adduction	Internal Rotation
Non Elite	1	40	-0.64 (0.11)	-0.13 (0.05)	0.07 (0.04)
		60	-0.51 (0.13)	-0.10 (0.07)	0.06 (0.02)
		80	-0.54 (0.12)	-0.09 (0.06)	0.05 (0.03)
	2	70%	-0.72 (0.07)	-0.16[a] (0.07)	0.08[a] (0.03)
		100%	-0.59 (0.08)	-0.15[a] (0.06)	0.07[a] (0.03)
		130%	-0.52 (0.09)	-0.09[a] (0.06)	0.05[a] (0.03)
Elite	1	40	-0.56 (0.06)	-0.16 (0.09)	0.06 (0.03)
		60	-0.46 (0.05)	-0.12 (0.06)	0.04 (0.01)
		80	-0.46 (0.09)	-0.09 (0.05)	0.04 (0.02)
	2	70%	-0.51 (0.07)	-0.13[a] (0.07)	0.05[a] (0.02)
		100%	-0.47 (0.05)	-0.11[a] (0.07)	0.05[a] (0.02)
		130%	-0.42 (0.06)	-0.09[a] (0.06)	0.04[a] (0.02)

Note: Peak moment unit is N•m•J^{-1}; values in parenthesis are standard deviation;
[*] Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix N

Group Table Right Normalized Hip Moment for Part III

Peak extension, adduction, and external rotation moments for the hip joint for Part III.

Group	Protocol	Height	Extension	Abduction	External Rotation
Non Elite	1	40	-0.87	0.27	-0.10
			(0.27)	(0.13)	(0.04)
		60	-0.75	0.19	-0.09
			(0.21)	(0.08)	(0.03)
		80	-0.63	0.22	-0.07
			(0.26)	(0.07)	(0.02)
	2	70%	-0.91	0.24	-0.10
			(0.38)	(0.08)	(0.04)
		100%	-0.83	0.25	-0.09
			(0.32)	(0.14)	(0.03)
		130%	-0.82	0.24	-0.09
			(0.22)	(0.12)	(0.03)
Elite	1	40	-0.66*	0.23	-0.09
			(0.18)	(0.12)	(0.04)
		60	-0.57*	0.24	-0.07
			(0.12)	(0.12)	(0.03)
		80	-0.49*	0.23	-0.06
			(0.21)	(0.11)	(0.02)
	2	70%	-0.74*	0.24	-0.08
			(0.23)	(0.12)	(0.04)
		100%	-0.58*	0.25	-0.07
			(0.14)	(0.14)	(0.03)
		130%	-0.49*	0.22	-0.06
			(0.20)	(0.15)	(0.03)

Note: Peak moment unit are $N \cdot m \cdot J^{-1}$; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix O

Group Table Eccentric Work for the Ankle, Knee and Hip Joint for Part III

Mean eccentric and relative work for the three lower extremity joints for Part III.

Group	Protocol	Height	Work				Percent Work		
			Ankle	Knee	Hip	Total	Ankle	Knee	Hip
Non Elite	1	40	-0.18	-0.30	-0.08	-0.55	31.55	51.92	16.54
			(0.07)	(0.10)	(0.04)	(0.11)	(11.22)	(10.92)	(7.73)
		60	-0.13	-0.27	-0.10	-0.51	26.10	53.31	20.59
			(0.04)	(0.07)	(0.05)	(0.10)	(8.13)	(8.09)	(10.81)
		80	-0.12	-0.28	-0.12	-0.52	23.07	53.60	23.33
			(0.02)	(0.06)	(0.05)	(0.09)	(3.23)	(7.11)	(7.33)
	2	70%	-0.20[a]	-0.32	-0.07	-0.59	35.08	52.57	12.35
			(0.08)	(0.12)	(0.04)	(0.14)	(12.45)	(8.51)	(7.84)
		100%	-0.18[a]	-0.29	-0.09	-0.55	32.79	51.49	15.72
			(0.06)	(0.08)	(0.05)	(0.08)	(11.73)	(8.03)	(8.15)
		130%	-0.14[a]	-0.28	-0.11	-0.53	28.54	50.0	21.47
			(0.04)	(0.07)	(0.04)	(0.11)	(7.66)	(8.14)	(5.41)
Elite	1	40	-0.21	-0.22	-0.07	-0.51	45.86	42.64	11.50
			(0.05)	(0.11)	(0.07)	(0.15)	(15.80)	(10.87)	(10.13)
		60	-0.16	-0.22	-0.07	-0.45	39.01	47.13	13.85
			(0.02)	(0.06)	(0.07)	(0.11)	(15.85)	(9.31)	(11.87)
		80	-0.13	-0.24	-0.09	-0.45	29.16	52.69	18.15
			(0.01)	(0.05)	(0.06)	(0.08)	(5.64)	(7.46)	(9.09)
	2	70%	-0.18[a]	-0.24	-0.08	-0.50	37.35	48.01	14.65
			(0.03)	(0.07)	(0.07)	(0.12)	(8.61)	(5.22)	(9.64)
		100%	-0.14[a]	-0.23	-0.08	-0.45	32.01	51.21	16.78
			(0.04)	(0.06)	(0.06)	(0.10)	(10.84)	(7.28)	(9.87)
		130%	-0.12[a]	-0.23	-0.10	-0.45	27.78	50.93	21.29
			(0.02)	(0.07)	(0.05)	(0.08)	(7.22)	(7.12)	(8.97)

Note: Work unit is in J•PE^{-1}; values in parenthesis are standard deviation; * Significantly different from non-elite; [a] Significantly different from protocol 1.

Appendix P

Group Table Right Ankle Angle for Part IV

Contact, peak angles, and ROM for the ankle joint for Part IV.

Gender	Group	PT	H	Contact	DF	DF ROM	Abd	Abd ROM	Ext Rotat	Ext Rotat ROM
Males	Non Elite	1	40	-11.9	33.5	45.5	-1.0	-7.4	-97.1	-6.5
				(8.3)	(5.5)	(8.5)	(3.5)	(4.4)	(8.2)	(2.5)
			60	-12.8	33.8	46.4	-0.6	-7.1	-97.4	-6.4
				(5.4)	(4.1)	(5.6)	(2.2)	(4.9)	(6.1)	(2.8)
			80	-14.9	35.2	50.0	-2.2	-9.0	-99.0	-8.2
				(3.7)	(4.4)	(5.1)	(3.0)	(5.3)	(6.0)	(3.2)
		2	70%	-13.0	33.4	46.2	-0.5	-6.6	-96.6	-6.1
				(6.6)	(5.8)	(7.8)	(3.2)	(4.2)	(6.2)	(1.3)
			100%	-13.5	34.6	47.4	-1.4	-8.4	-97.9	-7.3
				(6.1)	(5.2)	(7.5)	(3.3)	(4.9)	(7.2)	(2.3)
			130%	-14.1	33.9	47.9	-1.6	-7.8	-97.1	-8.6
				(5.1)	(4.0)	(6.8)	(3.0)	(4.9)	(7.2)	(7.3)
	Elite	1	40	-16.7	32.5	49.1	-3.7	-10.4	-101.9	-9.8
				(6.5)	(3.6)	(5.8)	(4.9)	(6.5)	(8.9)	(3.9)
			60	-16.2	34.7	50.1	-5.9	-13.1	-103.6	-12.9
				(5.9)	(3.6)	(7.2)	(4.4)	(6.9)	(6.3)	(7.6)
			80	-15.9	34.0	49.4	-6.4	-13.5	-104.0	-9.2
				(4.8)	(4.2)	(6.3)	(4.0)	(5.4)	(7.5)	(4.9)
		2	70%	-16.2	34.4	50.0	-4.44	-11.5	-102.3	-8.1
				(5.5)	(3.1)	(6.6)	(4.8)	(5.9)	(6.4)	(4.1)
			100%	-15.7	36.0	49.8	-7.21	-12.3	-104.5	-9.3
				(6.3)	(4.2)	(8.2)	(3.3)	(4.9)	(6.7)	(5.7)
			130%	-14.2	33.6	47.5	-7.34	-12.6	-104.3	-9.6
				(5.7)	(4.9)	(9.1)	(4.3)	(6.2)	(6.4)	(5.1)

Continued.

Gender	Group	PT	H	Contact	DF	DF ROM	Abd	Abd ROM	Ext Rotat	Ext Rotat ROM
Females	Non Elite	1	40	-18.3	28.2	45.3	-6.5	-12.5	-102.6	-9.3
				(5.1)	(5.4)	(4.9)	(4.4)	(5.6)	(5.5)	(4.0)
			60	-19.7	29.9	47.8	-5.6	-10.3	-100.0	-8.4
				(6.7)	(4.5)	(7.0)	(4.3)	(7.5)	(7.5)	(4.5)
			80	-18.3	30.5	47.1	-6.7	-12.8	-102.0	-9.4
				(4.7)	(5.0)	(6.2)	(4.2)	(6.1)	(5.7)	(4.6)
		2	70%	-16.0	25.5[a]	40.2[a]	-4.6	-11.6	-101.3	-9.0
				(7.4)	(4.0)	(7.4)	(3.3)	(6.1)	(4.5)	(2.2)
			100%	-16.8	27.8[a]	43.6[a]	-4.7	-10.8	-99.7	-7.2
				(7.9)	(4.7)	(5.0)	(3.7)	(7.4)	(6.5)	(2.9)
			130%	-19.9	28.7[a]	47.2[a]	-5.4	-10.8	-100.3	-9.3
				(4.7)	(3.8)	(6.5)	(3.2)	(5.5)	(6.6)	(3.9)
	Elite	1	40	-14.9	31.0	45.7	-5.0	-13.0	-98.2	-6.5
				(7.1)	(3.0)	(6.0)	(4.4)	(7.7)	(6.3)	(3.2)
			60	-17.7	31.1	48.2	-5.7	-13.0	-99.3	-7.2
				(6.2)	(2.9)	(4.7)	(4.6)	(9.0)	(6.8)	(3.8)
			80	-16.3	31.3	47.5	-7.7	-14.6	-102.4	-7.6
				(4.7)	(5.1)	(4.2)	(5.2)	(8.1)	(6.1)	(2.9)
		2	70%	-13.6	32.1	45.5	-6.0	-13.9	-99.1	-6.9
				(9.4)	(2.6)	(7.6)	(3.9)	(6.5)	(5.7)	(4.0)
			100%	-18.2	30.7	48.3	-5.4	-12.6	-99.3	-7.9
				(5.0)	(2.0)	(4.3)	(3.4)	(7.6)	(6.8)	(3.0)
			130%	-17.8	30.7	47.9	-6.5	-13.5	-100.3	-7.2
				(5.7)	(2.4)	(4.8)	(5.0)	(7.8)	(5.4)	(3.3)

Note: Angle units is degrees; values in parenthesis are standard deviation; [*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes.

Appendix Q

Group Table Right Ankle Angular Velocity for Part IV

Contact and peak angular velocities for the ankle joint for Part IV.

Gender	Group	PT	H	Contact	Dorsi-flexion	Abduction	External Rotation
Males	Non Elite	1	40	455.73 (86.64)	758.95 (120.85)	-172.12 (84.88)	-98.61 (50.80)
			60	567.48 (61.67)	872.91 (109.54)	-182.24 (53.39)	-107.09 (74.25)
			80	607.32 (117.39)	965.27 (59.88)	-236.38 (78.87)	-119.94 (65.60)
		2	70%	412.93[a] (76.66)	743.32[a] (106.27)	-166.91 (46.11)	-95.68 (45.09)
			100%	512.84[a] (116.80)	834.86[a] (116.39)	-190.31 (56.11)	-112.09 (54.06)
			130%	545.64[a] (118.08)	879.63[a] (97.71)	-202.0 (68.36)	-110.55 (51.59)
	Elite	1	40	442.77 (56.99)	798.70 (117.20)	-260.43 (93.84)	-145.55 (91.97)
			60	555.13 (71.78)	950.03 (89.63)	-300.55 (177.14)	-193.25 (121.55)
			80	615.68 (81.42)	954.21 (141.71)	-285.12 (179.13)	-148.41 (132.72)
		2	70%	492.33 (56.50)	864.28 (106.30)	-249.13 (127.61)	-134.20 (56.83)
			100%	638.15 (116.14)	974.08 (156.63)	-269.05 (158.0)	-203.58 (142.90)
			130%	606.27 (95.01)	917.34 (151.79)	-262.53 (148.46)	-154.33 (124.21)

Continued.

Gender	Group	PT	H	Contact	Dorsi-flexion	Abduction	External Rotation
Females	Non Elite	1	40	476.0 (61.33)	811.21 (68.48)	-208.70 (82.0)	-124.33 (33.76)
			60	551.58 (63.95)	901.24 (129.82)	-228.32 (75.06)	-120.38 (43.44)
			80	634.39 (133.31)	942.13 (168.03)	-251.78 (102.92)	-130.51 (44.01)
		2	70%	307.69[a] (57.16)	638.91[a] (75.81)	-201.24 (69.64)	-97.76[a] (15.44)
			100%	384.59[a] (67.55)	739.30[a] (93.28)	-176.85 (62.72)	-97.36[a] (19.33)
			130%	482.16[a] (75.40)	844.90[a] (91.75)	-236.22 (81.32)	-116.63[a] (29.81)
	Elite	1	40	496.81 (78.03)	757.92 (111.97)	-233.79 (49.90)	-83.95 (38.91)
			60	560.55 (71.02)	893.50 (121.15)	-260.72 (63.82)	-100.28 (54.74)
			80	628.51 (92.66)	989.84 (198.47)	-314.10 (115.39)	-202.63 (270.17)
		2	70%	430.19[a] (79.18)	701.60[a] (122.54)	-236.66 (54.37)	-90.69 (55.16)
			100%	520.94[a] (73.65)	839.30[a] (54.39)	-259.86 (66.81)	-94.10 (53.25)
			130%	603.99[a] (84.58)	920.52[a] (103.95)	-282.80 (55.29)	-119.77 (34.12)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes.

Appendix R

Group Table Right Knee Angle for Part IV

Contact, peak angles, and ROM for the knee joint.

Gender	Group	PT	H	Cont	Flex	Flex ROM	Add	Add ROM	Int Rotat	Int Rotat ROM
Males	Non Elite	1	40	-24.5	-82.3	-57.8	9.7	4.7	1.0	9.5
				(4.6)	(10.9)	(9.5)	(3.3)	(4.6)	(5.7)	(5.5)
			60	-26.2	-91.5	-65.4	9.9	4.9	3.2	6.1
				(4.7)	(8.1)	(9.3)	(3.6)	(4.7)	(4.1)	(10.1)
			80	-28.3	-104.8	-76.5	10.8	6.2	5.1	12.4
				(2.6)	(10.1)	(10.7)	(4.7)	(5.1)	(6.8)	(5.9)
		2	70%	17.0[a,1]	52.8[a,1]	36.0[1]	9.65[1]	4.9	0.39[a,1]	9.1
				(4.1)	(14.5)	(12.1)	(4.6)	(5.6)	(5.9)	(4.6)
			100%	19.2[a,1]	64.3[a,1]	43.0[1]	10.44[1]	5.5	1.16[a,1]	10.9
				(3.2)	(11.8)	(10.6)	(3.9)	(5.5)	(6.4)	(5.4)
			130%	24.2[a,1]	80.2[a,1]	56.0[1]	10.03[1]	5.6	3.54[a,1]	10.4
				(2.5)	(8.3)	(8.7)	(3.3)	(4.8)	(5.4)	(4.7)
	Elite	1	40	-20.2	-77.4	-57.2	14.1	5.7	7.9	16.6
				(4.9)	(16.4)	(14.4)	(6.2)	(4.4)	(8.1)	(5.9)
			60	-25.1	-92.5	-67.4	14.8	5.4	12.1	19.2
				(4.8)	(13.2)	(13.6)	(6.7)	(6.3)	(7.2)	(6.4)
			80	-27.8	-101.7	-74.1	15.8	6.2	15.3	20.6
				(5.7)	(13.1)	(13.7)	(7.8)	(6.7)	(7.0)	(7.8)
		2	70%	21.5[a]	62.0[a]	-62.8	14.7	6.0	10.4	18.6
				(4.4)	(12.5)	(14.2)	(7.9)	(6.5)	(7.0)	(6.2)
			100%	24.1[a]	75.5[a]	-71.5	15.5	5.7	15.5	20.9
				(4.6)	(13.1)	(14.7)	(8.8)	(7.0)	(8.5)	(8.4)
			130%	27.2[a]	85.8[a]	-72.5	16.3	6.4	15.9	21.1
				(4.9)	(13.0)	(11.4)	(8.3)	(7.1)	(8.2)	(8.4)

Continued.

Gender	Group	PT	H	Cont	Flex	Flex ROM	Add	Add ROM	Int Rotat	Int Rotat ROM
Females	Non Elite	1	40	-22.1	-75.6	-50.9	6.9	5.3	8.2	9.1
				(4.3)	(13.4)	(14.3)	(4.2)	(3.2)	(4.8)	(4.4)
			60	-25.6	-88.5	-60.3	7.4	4.1	10.9	11.7
				(5.3)	(14.4)	(16.9)	(6.3)	(3.9)	(5.7)	(6.9)
			80	-27.5	-98.7	-71.2	9.4	6.0	13.2	13.4
				(4.8)	(11.9)	(10.5)	(5.3)	(5.3)	(5.7)	(7.2)
		2	70%	10.8[a,1]	32.9[a,1]	19.7[a,1]	5.6[a,1]	0.5[1]	7.98[1]	9.2
				(5.9)	(13.8)	(11.2)	(4.1)	(2.3)	(6.1)	(2.8)
			100%	17.4[a,1]	46.1[a,1]	26.8[a,1]	5.8[a,1]	-0.1[1]	8.31[1]	9.7
				(6.2)	(15.2)	(13.4)	(5.6)	(4.4)	(5.9)	(3.9)
			130%	18.6[a,1]	54.0[a,1]	33.5[a,1]	6.4[a,1]	0.6[1]	9.22[1]	9.6
				(5.4)	(15.1)	(14.0)	(5.1)	(4.1)	(5.6)	(4.9)
	Elite	1	40	-25.6	-92.3	-66.7	11.2	4.7	11.0	17.4
				(4.5)	(18.9)	(16.9)	(6.0)	(3.7)	(12.4)	(11.1)
			60	-27.7	-103.9	-76.2	12.2	5.0	13.1	19.0
				(6.2)	(15.8)	(15.1)	(5.4)	(4.9)	(11.5)	(10.9)
			80	-30.3	-111.2	-80.9	13.9	5.8	17.0	20.9
				(5.8)	(13.7)	(11.1)	(6.3)	(5.2)	(12.2)	(10.0)
		2	70%	-27.1	65.6[a]	45.5[a]	11.2	4.3	11.7	17.8
				(8.2)	(19.6)	(16.7)	(5.0)	(3.5)	(11.7)	(10.2)
			100%	-27.2	-100.4[a]	56.0[a]	11.6	5.4	11.6	18.2
				(6.0)	(12.0)	(11.4)	(5.7)	(5.3)	(10.1)	(8.8)
			130%	-29.1	85.4[a]	62.6[a]	13.1	4.8	14.7	19.7
				(6.4)	(16.1)	(13.2)	(5.9)	(4.9)	(12.9)	(10.3)

Note: Angle units is degrees; values in parenthesis are standard deviation; [*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes.

Appendix S

Group Table Right Knee Angular Velocity for Part IV

Contact and peak velocities for the knee joint.

Gender	Group	Protocol	Height	Contact	Flexion	Adduction	Internal Rotation
Males	Non Elite	1	40	-270.0 (49.37)	-509.24 (50.64)	100.51 (27.98)	131.97 (27.94)
			60	-309.05 (30.38)	-596.39 (49.18)	142.96 (58.50)	134.05 (41.25)
			80	-355.75 (57.27)	-700.79 (38.96)	171.07 (55.92)	133.95 (68.44)
		2	70%	-241.52[a] (42.17)	-466.96[a] (48.57)	97.52 (43.90)	127.37 (33.68)
			100%	-294.64[a] (36.09)	-554.72[a] (56.24)	115.20 (43.89)	141.61 (48.98)
			130%	-329.40[a] (51.91)	-623.46[a] (67.66)	145.75 (37.64)	113.06 (52.79)
	Elite	1	40	-282.59 (67.58)	-498.05 (52.24)	142.49 (56.52)	138.07 (61.93)
			60	-348.42 (62.79)	-564.95 (19.28)	173.06 (80.40)	149.70 (98.92)
			80	-385.96 (61.93)	-631.44 (46.34)	187.62 (91.92)	119.86 (95.29)
		2	70%	-315.78 (57.69)	-532.25[a] (46.47)	145.69 (69.02)	127.02 (56.14)
			100%	-375.94 (53.88)	-607.75[a] (22.71)	182.83 (100.74)	146.39 (92.59)
			130%	-392.24 (90.96)	-646.27[a] (49.57)	199.26 (89.10)	144.65 (83.45)

Continued.

Gender	Group	Protocol	Height	Contact	Flexion	Adduction	Internal Rotation
Females	Non Elite	1	40	-301.99 (43.92)	-536.71 (49.43)	110.69 (35.23)	142.18 (58.12)
			60	-349.46 (65.04)	-621.57 (63.16)	138.58 (51.27)	155.87 (40.77)
			80	-398.61 (68.20)	-714.74 (95.80)	178.21 (41.67)	155.97 (66.69)
		2	70%	-191.04[a] (60.89)	-407.96[a] (54.97)	95.01[a] (30.13)	124.12 (37.34)
			100%	-254.09[a] (70.11)	-466.15[a] (74.76)	91.88[a] (33.70)	122.88 (39.29)
			130%	-325.16[a] (62.34)	-527.55[a] (61.77)	111.93[a] (45.88)	149.69 (43.16)
	Elite	1	40	-346.27 (78.23)	-586.18 (94.77)	130.57 (48.88)	91.32 (40.30)
			60	-402.29 (59.96)	-658.21 (85.14)	149.11 (36.68)	117.42 (62.94)
			80	-415.67 (84.93)	-746.50 (82.38)	195.29 (53.60)	113.67 (60.03)
		2	70%	-326.05 (82.53)	-564.27[a] (76.04)	123.26 (49.94)	106.19 (53.63)
			100%	-371.80 (82.20)	-633.59[a] (82.54)	146.90 (52.20)	119.48 (56.63)
			130%	-421.61 (88.05)	-683.77[a] (80.37)	168.36 (49.63)	124.78 (66.51)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes

Appendix T

Group Table Right Hip Angle for Part IV

Contact, peak angles, and ROM for the hip joint

Gender	Group	PT	H	Cont	Flex	Flex ROM	Abd	Abd ROM	Int Rotat	Int Rotat ROM
Males	Non Elite	1	40	18.8	59.4	41.1	-10.7	-1.0	5.2	4.0
				(5.6)	(16.1)	(14.4)	(6.2)	(4.5)	(2.2)	(2.0)
			60	23.2	75.0	49.4	-10.9	-2.2	12.0	14.1
				(6.0)	(13.7)	(9.8)	(6.5)	(5.5)	(19.8)	(33.2)
			80	27.4	94.5	62.5	-12.1	-1.4	10.9	9.8
				(5.8)	(13.8)	(11.4)	(5.9)	(5.1)	(8.8)	(6.6)
		2	70%	17.0[a,1]	52.8[a,1]	36.0[1]	-9.5	-1.0[1]	4.5	2.6
				(4.7)	(16.1)	(14.3)	(6.2)	(3.4)	(3.4)	(1.5)
			100%	19.2[a,1]	64.3[a,1]	43.0[1]	-10.7	-1.6[1]	5.3	5.1
				(6.6)	(18.9)	(14.0)	(6.0)	(5.6)	(4.1)	(5.5)
			130%	24.2[a,1]	80.2[a,1]	56.0[1]	-10.8	-1.2[1]	6.6	5.7
				(4.5)	(10.0)	(10.4)	(5.5)	(4.3)	(4.6)	(5.6)
	Elite	1	40	17.3	52.4	35.1	-12.2	-3.9	8.7	4.9
				(8.6)	(23.1)	(20.0)	(8.2)	(6.6)	(9.0)	(3.6)
			60	23.5	67.5	44.0	-14.8	-5.0	10.2	7.7
				(8.8)	(22.3)	(18.7)	(10.5)	(6.9)	(10.3)	(7.3)
			80	25.9	82.1	56.2	-16.6	-6.7	9.1	9.1
				(8.5)	(20.0)	(17.5)	(11.5)	(8.0)	(8.9)	(9.1)
		2	70%	21.5[a]	62.0[a]	40.5	-12.7	-4.4	8.7	6.5
				(8.0)	(21.1)	(19.5)	(11.6)	(7.1)	(11.3)	(6.0)
			100%	24.1[a]	75.5[a]	51.6	-15.4	-5.5	11.3	8.7
				(9.4)	(22.0)	(20.1)	(13.2)	(8.6)	(9.6)	(8.2)
			130%	27.2[a]	85.8[a]	56.5	-16.5	-5.5	9.5	8.2
				(10.1)	(23.1)	(17.7)	(8.8)	(6.8)	(7.1)	(9.5)

Continued.

Gender	Group	PT	H	Cont	Flex	Flex ROM	Abd	Abd ROM	Int Rotat	Int Rotat ROM
Females	Non Elite	1	40	17.2	51.8	33.2	-4.4	0.3	5.3	0.6
				(6.4)	(23.1)	(20.7)	(12.7)	(6.8)	(7.9)	(8.1)
			60	23.9	70.3	45.7	-10.8	-2.4	4.5	3.2
				(9.7)	(32.9)	(24.7)	(13.9)	(7.0)	(6.9)	(8.4)
			80	27.3	87.9	60.6	-13.8	-3.5	6.5	7.8
				(9.5)	(27.9)	(21.8)	(18.4)	(10.7)	(4.6)	(20.8)
		2	70%	10.8[a,1]	32.9[a,1]	19.7[a,1]	-4.0	0.5[1]	7.5	1.2
				(7.4)	(19.1)	(15.3)	(10.6)	(6.5)	(15.1)	(4.9)
			100%	17.4[a,1]	46.1[a,1]	26.8[a,1]	-6.6	-0.1[1]	3.3	0.8
				(6.2)	(26.6)	(23.8)	(11.5)	(6.9)	(14.5)	(3.3)
			130%	18.6[a,1]	54.0[a,1]	33.5[a,1]	-5.5	0.6[1]	3.8	1.8
				(6.2)	(27.1)	(23.9)	(17.2)	(9.6)	(10.2)	(7.8)
	Elite	1	40	21.8	69.4	49.1	-10.4	-5.0	4.4	-2.0
				(6.6)	(26.5)	(20.6)	(9.1)	(7.4)	(7.4)	(8.0)
			60	22.8	89.6	66.8	-16.8	-9.5	12.4	7.9
				(10.5)	(28.6)	(29.5)	(21.7)	(14.9)	(19.6)	(31.8)
			80	28.8	100.3	72.1	-16.2	-9.8	8.5	4.3
				(7.7)	(18.1)	(16.6)	(12.5)	(9.1)	(9.4)	(15.5)
		2	70%	21.4	65.6[a]	45.5[a]	-11.2	-6.0	5.1	-2.6
				(9.8)	(26.8)	(18.9)	(10.7)	(9.2)	(8.6)	(10.2)
			100%	26.1	82.0[a]	56.0[a]	-11.2	-4.8	6.0	-1.0
				(8.0)	(23.6)	(18.2)	(8.2)	(5.8)	(8.4)	(4.0)
			130%	27.0	85.4[a]	62.6[a]	-15.6	-8.7	7.6	2.7
				(8.4)	(19.6)	(16.8)	(12.6)	(10.1)	(9.2)	(8.6)

Note: Angle units is degrees; values in parenthesis are standard deviation; [*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes.

Appendix U

Group Table Right Hip Angular Velocity for Part IV

Contact and peak velocities for the hip joint.

Gender	Group	Protocol	Height	Contact	Flexion	Abduction	Internal Rotation
Males	Non Elite	1	40	137.70	365.45	-84.78	144.86
				(34.49)	(83.18)	(13.43)	(46.70)
			60	156.41	444.87	-152.04	175.26
				(42.71)	(57.20)	(86.64)	(52.39)
			80	197.34	541.49	-147.40	166.61
				(38.45)	(31.16)	(37.88)	(30.83)
		2	70%	114.77[a]	316.17[a]	-81.72[a]	152.28
				(37.86)	(73.90)	(19.93)	(30.59)
			100%	143.50[a]	404.35[a]	-93.46[a]	158.44
				(37.05)	(84.04)	(22.59)	(39.40)
			130%	171.25[a]	471.68[a]	-113.63[a]	155.72
				(45.97)	(60.14)	(27.38)	(26.22)
	Elite	1	40	133.73	299.17	-97.42	119.95
				(77.57)	(92.26)	(64.29)	(48.33)
			60	160.94	357.73	-130.0	133.57
				(73.07)	(61.10)	(75.45)	(64.85)
			80	184.80	440.10	-130.74	130.12
				(85.53)	(66.66)	(57.30)	(51.33)
		2	70%	148.52	332.80[a]	-108.25	128.94
				(73.83)	(75.80)	(58.24)	(73.15)
			100%	180.95	386.06[a]	-129.17	131.74
				(68.98)	(80.21)	(53.81)	(59.01)
			130%	195.62	444.61[a]	-136.70	140.77
				(86.43)	(60.64)	(61.90)	(55.80)

Continued.

Gender	Group	Protocol	Height	Contact	Flexion	Abduction	Internal Rotation
Females	Non Elite	1	40	144.05 (47.47)	331.59 (124.55)	-77.0 (37.28)	106.54 (39.18)
			60	186.52 (54.83)	419.20 (162.32)	-106.68 (39.53)	106.59 (47.04)
			80	232.06 (84.22)	546.05 (159.68)	-139.55 (51.35)	126.61 (58.82)
		2	70%	82.55[a] (56.87)	226.56[a] (79.86)	-64.64[a] (17.02)	100.81 (45.10)
			100%	109.30[a] (76.17)	262.07[a] (104.45)	-66.41[a] (18.10)	104.60 (48.93)
			130%	158.65[a] (65.08)	335.11[a] (127.76)	-84.92[a] (42.62)	114.54 (39.93)
	Elite	1	40	174.41 (84.91)	376.29 (121.43)	-85.83 (42.42)	79.40 (47.65)
			60	224.25 (70.50)	475.75 (99.78)	-104.19 (25.53)	84.79 (45.08)
			80	238.93 (77.80)	580.43 (80.27)	-127.03 (56.96)	76.62 (39.86)
		2	70%	163.43 (72.78)	348.45[a] (92.57)	-79.58 (34.29)	80.76 (46.03)
			100%	194.17 (66.92)	431.61[a] (100.24)	-97.84 (36.34)	89.56 (34.19)
			130%	221.84 (77.08)	492.57[a] (90.40)	-121.34 (57.96)	90.37 (50.93)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation; [*] Significantly different from non-elite; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 non-elite athletes.

Appendix V

Group Table GRF Data for Part IV

GRF Force

Grp	PT	H	BF	T BF	F1	T F1	F2	T F2	LRate1	LRate2	TI
NEM	1	40	-1.34	1.53	2.68	0.01	6.09	0.06	369.72	132.83	1.01
			(0.33)	(0.60)	(0.58)	(0.01)	(1.12)	(0.01)	(155.53)	(49.13)	(0.11)
		60	-1.47	1.45	2.81	0.01	5.29	0.05	377.25	140.43	0.75
			(0.33)	(0.24)	(0.53)	(0.0)	(0.39)	(0.01)	(143.17)	(31.52)	(0.05)
		80	-1.45	1.35	3.07	0.01	4.67	0.04	446.84	142.66	0.59
			(0.22)	(0.25)	(0.32)	(0.0)	(0.60)	(0.0)	(145.57)	(36.94)	(0.04)
	2	70%	-1.34	1.69	2.73	0.01	6.99[1]	0.06	294.26	135.41	1.23[a,1]
			(0.35)	(0.72)	(0.60)	(0.0)	(1.67)	(0.01)	(148.90)	(54.87)	(0.14)
		100%	-1.37	1.46	2.75	0.01	5.78[1]	0.05	429.01	127.93	0.95[a,1]
			(0.30)	(0.48)	(0.35)	(0.0)	(0.91)	(0.01)	(231.24)	(42.90)	(0.14)
		130%	-1.46	1.44	2.90	0.01	5.27[1]	0.05	399.25	126.97	0.74[a,1]
			(0.41)	(0.38)	(0.53)	(0.0)	(0.54)	(0.01)	(160.05)	(47.03)	(0.11)
EM	1	40	-1.26	1.04	2.81	0.01	5.39	0.07	296.87	91.11	0.99
			(0.22)	(0.37)	(0.62)	(0.0)	(0.94)	(0.01)	(66.38)	(31.50)	(0.05)
		60	-1.20	1.03	2.87	0.01	4.40	0.06	326.19	90.75	0.73
			(0.15)	(0.25)	(0.48)	(0.0)	(0.86)	(0.01)	(64.65)	(31.88)	(0.01)
		80	-1.19	0.94	2.90	0.01	3.74	0.05	381.49	91.80	0.58
			(0.25)	(0.39)	(0.64)	(0.0)	(0.95)	(0.01)	(132.51)	(48.59)	(0.03)
	2	70%	-1.19	1.13	2.71	0.01	4.75[a]	0.06	285.87	90.49	0.84[a]
			(0.18)	(0.41)	(0.54)	(0.0)	(1.33)	(0.01)	(82.01)	(47.83)	(0.08)
		100%	-1.17	0.93	2.81	0.01	3.82[a]	0.05	327.39	81.06	0.65[a]
			(0.16)	(0.36)	(0.51)	(0.0)	(1.01)	(0.01)	(83.56)	(40.51)	(0.05)
		130%	-1.27	0.89	2.89	0.01	3.63[a]	0.05	431.27	99.02	0.52[a]
			(0.31)	(0.41)	(0.75)	(0.0)	(0.97)	(0.01)	(179.01)	(45.01)	(0.05)

Continued.

Grp	PT	H	BF	T BF	F1	T F1	F2	T F2	LRate1	LRate2	TI
NEF	1	40	-1.58	1.34	3.57	0.01	6.64	0.06	442.58	128.16	1.12
			(0.47)	(0.63)	(0.76)	(0.0)	(1.56)	(0.01)	(190.82)	(78.46)	(0.11)
		60	-1.52	1.26	3.50	0.01	5.18	0.05	465.56	116.63	0.77
			(0.31)	(0.52)	(0.87)	(0.0)	(1.02)	(0.01)	(240.76)	(52.50)	(0.08)
		80	-1.51	1.31	3.44	0.01	4.99	0.04	601.89	150.24	0.62
			(0.40)	(0.55)	(0.64)	(0.0)	(1.36)	(0.01)	(166.07)	(81.46)	(0.03)
	2	70%	-1.30	1.53	2.97	0.02[a]	9.18[a,1]	0.08[a]	287.79[a]	129.70	1.73[a,1]
			(0.49)	(1.03)	(1.41)	(0.01)	(3.14)	(0.02)	(180.25)	(96.08)	(0.21)
		100%	-1.32	1.23	2.98	0.01[a]	7.01[a,1]	0.07[a]	302.93[a]	101.13	1.30[a,1]
			(0.43)	(0.72)	(0.98)	(0.0)	(2.10)	(0.01)	(138.63)	(45.64)	(0.16)
		130%	-1.55	1.30	3.57	0.01[a]	6.48[a,1]	0.06[a]	391.70[a]	113.37	1.10[a,1]
			(0.37)	(0.54)	(0.74)	(0.0)	(1.70)	(0.01)	(141.84)	(46.72)	(0.13)
EF	1	40	-1.17	1.36	2.58	0.01	5.44	0.06	375.40	132.31	1.0
			(0.33)	(0.84)	(0.33)	(0.0)	(1.55)	(0.02)	(120.96)	(109.82)	(0.09)
		60	-1.27	1.10	2.92	0.01	4.36	0.05	513.49	95.38	0.72
			(0.16)	(0.49)	(0.42)	(0.0)	(1.03)	(0.01)	(164.88)	(54.74)	(0.05)
		80	-1.48	1.24	3.07	0.01	4.38	0.04	642.08	131.78	0.59
			(0.23)	(0.47)	(0.35)	(0.0)	(0.95)	(0.01)	(463.57)	(61.16)	(0.04)
	2	70%	-1.14	1.29	2.67	0.01	5.29	0.06[a]	385.88	111.56	1.08[a]
			(0.33)	(0.78)	(0.82)	(0.0)	(1.42)	(0.02)	(214.80)	(75.62)	(0.16)
		100%	-1.30	1.26	2.85	0.01	5.01	0.06[a]	407.36	121.09	0.84[a]
			(0.27)	(0.65)	(0.16)	(0.0)	(1.21)	(0.02)	(226.36)	(85.02)	(0.11)
		130%	-1.33	1.17	2.98	0.01	4.45	0.05[a]	454.44	110.12	0.66[a]
			(0.29)	(0.54)	(0.36)	(0.0)	(1.24)	(0.01)	(179.43)	(63.45)	(0.09)

Note: Force units are $N \cdot J^{-1}$ Loading Rate units are $N \cdot s^{-1} \cdot J^{-1}$;values in parenthesis are standard deviation; [*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 for non-elite athletes.

Appendix W

Group Table Right Normalized Ankle Moment for Part IV

Right normalized ankle moment

Gender	Group	Protocol	Height	Plantar Flexion	Adduction	Internal Rotation
Males	Non Elite	1	40	-0.39 (0.13)	-0.01 (0.02)	0.03 (0.03)
			60	-0.28 (0.08)	-0.02 (0.01)	0.02 (0.01)
			80	-0.22 (0.05)	-0.01 (0.02)	0.02 (0.01)
		2	70%	-0.44[a,1] (0.13)	-0.01 (0.03)	0.02 (0.02)
			100%	-0.35[a,1] (0.09)	-0.01 (0.01)	0.02 (0.02)
			130%	-0.27[a,1] (0.08)	-0.01 (0.02)	0.02 (0.02)
	Elite	1	40	-0.47 (0.08)	-0.02 (0.02)	0.01 (0.01)
			60	-0.32 (0.05)	-0.02 (0.03)	0.01 (0.01)
			80	-0.25 (0.04)	-0.01 (0.02)	0.0 (0.01)
		2	70%	-0.36[a] (0.05)	-0.02 (0.01)	0.01 (0.01)
			100%	-0.28[a] (0.05)	-0.02 (0.02)	0.01 (0.01)
			130%	-0.23[a] (0.06)	-0.01 (0.02)	0.01 (0.01)

Continued.

Gender	Group	Protocol	Height	Plantar Flexion	Adduction	Internal Rotation
Females	Non Elite	1	40	-0.47 (0.11)	-0.02 (0.03)	0.06 (0.04)
			60	-0.33 (0.07)	-0.03 (0.03)	0.04 (0.01)
			80	-0.25 (0.03)	-0.01 (0.02)	0.03 (0.02)
		2	70%	-0.69[a,1] (0.18)	-0.05 (0.13)	0.04 (0.02)
			100%	-0.51[a,1] (0.12)	-0.03 (0.09)	0.04 (0.02)
			130%	-0.46[a,1] (0.10)	-0.05 (0.12)	0.04 (0.02)
	Elite	1	40	-0.36 (0.06)	-0.02 (0.04)	0.04 (0.04)
			60	-0.28 (0.05)	-0.01 (0.02)	0.04 (0.02)
			80	-0.23 (0.03)	-0.02 (0.02)	0.03 (0.02)
		2	70%	-0.36 (0.08)	-0.02 (0.04)	0.03 (0.03)
			100%	-0.31 (0.08)	-0.02 (0.06)	0.04 (0.02)
			130%	-0.26 (0.05)	-0.01 (0.02)	0.03 (0.01)

Note: Peak moment unit is N•m•J^{-1}; values in parenthesis are standard deviation;[*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 for non-elite athletes.

Appendix X

Group Table Right Normalized Knee Moment for Part IV

Right normalized knee moment.

Gender	Group	Protocol	Height	Extension	Adduction	Internal Rotation
Males	Non Elite	1	40	-0.64 (0.11)	-0.13 (0.05)	0.07 (0.04)
			60	-0.51 (0.13)	-0.10 (0.07)	0.06 (0.02)
			80	-0.54 (0.12)	-0.09 (0.06)	0.05 (0.03)
		2	70%	-0.72[1] (0.07)	-0.16 (0.07)	0.08 (0.03)
			100%	-0.59[1] (0.08)	-0.15 (0.06)	0.07 (0.03)
			130%	-0.52[1] (0.09)	-0.09 (0.06)	0.05 (0.03)
	Elite	1	40	-0.56 (0.06)	-0.16 (0.09)	0.06 (0.03)
			60	-0.46 (0.05)	-0.12 (0.06)	0.04 (0.01)
			80	-0.46 (0.09)	-0.09 (0.05)	0.04 (0.02)
		2	70%	-0.51 (0.07)	-0.13 (0.07)	0.05 (0.02)
			100%	-0.47 (0.05)	-0.11 (0.07)	0.05 (0.02)
			130%	-0.42 (0.06)	-0.09 (0.06)	0.04 (0.02)

Continued.

Gender	Group	Protocol	Height	Extension	Adduction	Internal Rotation
Females	Non Elite	1	40	-0.57 (0.12)	-0.12 (0.05)	0.08 (0.03)
			60	-0.50 (0.09)	-0.09 (0.05)	0.06 (0.02)
			80	-0.42 (0.10)	-0.07 (0.03)	0.05 (0.03)
		2	70%	-0.72[a,1] (0.16)	-0.17 (0.10)	0.11 (0.06)
			100%	-0.59[a,1] (0.15)	-0.10 (0.05)	0.07 (0.04)
			130%	-0.57[a,1] (0.12)	-0.13 (0.06)	0.09 (0.04)
	Elite	1	40	-0.49 (0.08)	-0.12 (0.05)	0.06 (0.03)
			60	-0.40 (0.04)	-0.09 (0.04)	0.05 (0.01)
			80	-0.39 (0.06)	-0.10 (0.05)	0.05 (0.02)
		2	70%	-0.52[a] (0.10)	-0.13 (0.06)	0.07 (0.03)
			100%	-0.45[a] (0.08)	-0.12 (0.07)	0.06 (0.03)
			130%	-0.44[a] (0.10)	-0.08 (0.04)	0.04 (0.01)

Note: Peak moment unit is N•m•J^{-1}; values in parenthesis are standard deviation; * Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 for non-elite athletes.

Appendix Y

Group Table Right Normalized Hip Moment for Part IV

Right normalized hip moment.

Gender	Group	Protocol	Height	Extension	Abduction	External Rotation
Males	Non Elite	1	40	-0.87 (0.27)	0.27 (0.13)	-0.10 (0.04)
			60	-0.75 (0.21)	0.19 (0.08)	-0.09 (0.03)
			80	-0.63 (0.26)	0.22 (0.07)	-0.07 (0.02)
		2	70%	-0.91 (0.38)	0.24 (0.08)	-0.10 (0.04)
			100%	-0.83 (0.32)	0.25 (0.14)	-0.09 (0.03)
			130%	-0.82 (0.22)	0.24 (0.12)	-0.09 (0.03)
	Elite	1	40	-0.66 (0.18)	0.23 (0.12)	-0.09 (0.04)
			60	-0.57 (0.12)	0.24 (0.12)	-0.07 (0.03)
			80	-0.49 (0.21)	0.23 (0.11)	-0.06 (0.02)
		2	70%	-0.74 (0.23)	0.24 (0.12)	-0.08 (0.04)
			100%	-0.58 (0.14)	0.25 (0.14)	-0.07 (0.03)
			130%	-0.49 (0.20)	0.22 (0.15)	-0.06 (0.03)

Continued.

Gender	Group	Protocol	Height	Extension	Abduction	External Rotation
Females	Non Elite	1	40	-0.76 (0.31)	0.20 (0.15)	-0.11 (0.05)
			60	-0.63 (0.17)	0.19 (0.12)	-0.09 (0.02)
			80	-0.66 (0.21)	0.28 (0.28)	-0.10 (0.06)
		2	70%	-0.83 (0.50)	0.11 (0.11)	-0.09 (0.04)
			100%	-0.69 (0.29)	0.14 (0.10)	-0.09 (0.03)
			130%	-0.74 (0.26)	0.20 (0.15)	-0.12 (0.04)
	Elite	1	40	-0.75 (0.46)	0.17 (0.11)	-0.09 (0.05)
			60	-0.55 (0.22)	0.19 (0.09)	-0.07 (0.02)
			80	-0.65 (0.24)	0.19 (0.12)	-0.08 (0.05)
		2	70%	-0.75 (0.36)	0.18 (0.08)	-0.09 (0.05)
			100%	-0.72 (0.27)	0.15 (0.08)	-0.10 (0.03)
			130%	-0.68 (0.30)	0.17 (0.05)	-0.07 (0.04)

Note: Peak moment unit is N•m•J^{-1}; values in parenthesis are standard deviation; * Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 for non-elite athletes.

Appendix Z

Group Table Eccentric Work for the Ankle, Knee and Hip Joint for Part IV

Mean ankle, knee and hip eccentric work.

Gender	Group	PT	H	Work Ankle	Work Knee	Work Hip	Work Total	Percent Work Ankle	Percent Work Knee	Percent Work Hip
Males	Non Elite	1	40	-0.18 (0.07)	-0.30 (0.10)	-0.08 (0.04)	-0.55 (0.11)	31.55 (11.22)	51.92 (10.92)	16.54 (7.73)
			60	-0.13 (0.04)	-0.27 (0.07)	-0.10 (0.05)	-0.51 (0.10)	26.10 (8.13)	53.31 (8.09)	20.59 (10.81)
			80	-0.12 (0.02)	-0.28 (0.06)	-0.12 (0.05)	-0.52 (0.09)	23.94 (3.49)	53.65 (7.07)	22.41 (6.85)
		2	70%	-0.20[a,1] (0.08)	-0.32 (0.12)	-0.07 (0.04)	-0.59 (0.14)	35.08 (12.45)	52.57 (8.51)	12.35 (7.84)
			100%	-0.18[a,1] (0.06)	-0.29 (0.08)	-0.09 (0.05)	-0.55 (0.08)	32.79 (11.73)	51.49 (8.03)	15.72 (8.15)
			130%	-0.14[a,1] (0.04)	-0.28 (0.07)	-0.11 (0.04)	-0.53 (0.11)	28.54 (7.66)	50.0 (8.14)	21.47 (5.41)
	Elite	1	40	-0.21 (0.05)	-0.22 (0.11)	-0.07 (0.07)	-0.51 (0.15)	45.86 (15.80)	42.64 (10.87)	11.50 (10.13)
			60	-0.16 (0.02)	-0.22 (0.06)	-0.07 (0.07)	-0.45 (0.11)	39.01 (15.85)	47.13 (9.31)	13.85 (11.87)
			80	-0.13 (0.01)	-0.24 (0.05)	-0.09 (0.06)	-0.45 (0.08)	29.16 (5.64)	52.69 (7.46)	18.15 (9.09)
		2	70%	-0.18[a] (0.03)	-0.24 (0.07)	-0.08 (0.07)	-0.50 (0.12)	37.35 (8.61)	48.01 (5.22)	14.65 (9.64)
			100%	-0.14[a] (0.04)	-0.23 (0.06)	-0.08 (0.06)	-0.45 (0.10)	32.01 (10.84)	51.21 (7.28)	16.78 (9.87)
			130%	-0.12[a] (0.02)	-0.23 (0.07)	-0.10 (0.05)	-0.45 (0.08)	27.78 (7.22)	50.93 (7.12)	21.29 (8.97)

Continued.

Gender	Group	PT	H	Work Ankle	Work Knee	Work Hip	Work Total	Percent Work Ankle	Percent Work Knee	Percent Work Hip
Females	Non Elite	1	40	-0.21	-0.21	-0.07	-0.61	29.25	44.21	26.55
				(0.04)	(0.12)	(0.05)	(0.15)	(9.72)	(9.49)	(13.16)
			60	-0.16	-0.21	-0.10	-0.54	25.54	47.12	27.35
				(0.04)	(0.06)	(0.09)	(0.13)	(7.73)	(9.62)	(14.25)
			80	-0.13	-0.22	-0.11	-0.49	21.28	44.72	34.01
				(0.03)	(0.05)	(0.07)	(0.09)	(2.96)	(10.82)	(10.67)
		2	70%	-0.25[a,1]	-0.14[a]	-0.05	-0.57	32.71	43.33	23.97
				(0.04)	(0.07)	(0.05)	(0.13)	(15.42)	(13.50)	(8.52)
			100%	-0.22[a,1]	-0.18[a]	-0.08	-0.58	29.58	42.41	28.01
				(0.06)	(0.07)	(0.08)	(0.12)	(13.70)	(10.16)	(11.28)
			130%	-0.2[a,1]	-0.20[a]	-0.09	-0.53	29.11	41.89	29.01
				(0.03)	(0.08)	(0.08)	(0.09)	(11.36)	(10.38)	(13.47)
	Elite	1	40	-0.16	-0.24	-0.15	-0.44	48.48	40.92	10.60
				(0.05)	(0.09)	(0.15)	(0.14)	(13.56)	(13.77)	(4.11)
			60	-0.14	-0.24	-0.14	-0.46	39.39	43.97	16.64
				(0.03)	(0.06)	(0.10)	(0.08)	(8.89)	(8.05)	(10.29)
			80	-0.12	-0.21	-0.15	-0.46	31.11	46.99	21.90
				(0.02)	(0.03)	(0.07)	(0.05)	(5.55)	(9.89)	(11.27)
		2	70%	-0.16	-0.24	-0.12	-0.39	58.96	32.08	8.96
				(0.05)	(0.10)	(0.11)	(0.08)	(13.87)	(11.61)	(6.91)
			100%	-0.156	-0.25	-0.15	-0.45	48.52	39.83	11.65
				(0.05)	(0.07)	(0.08)	(0.06)	(14.46)	(11.51)	(6.01)
			130%	-0.13	-0.22	-0.14	-0.48	41.95	42.82	15.22
				(0.03)	(0.05)	(0.08)	(0.09)	(10.38)	(8.19)	(7.84)

Note: Work units is $J \cdot PE^{-1}$; values in parenthesis are standard deviation; [*] Significantly different from males; [a] Significantly different from protocol 1; [1] Significantly different from protocol 1 for non-elite athletes.

Appendix AA

Male Subject Table for Right Ankle Angle Data

Male subject right ankle angle data.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
2	1	-15.63 (2.19)	22.77 (1.14)	38.41 (2.43)	2.73 (0.70)	-5.54 (2.44)	-91.77 (0.31)	-5.63 (2.65)
	2	-14.02 (1.57)	25.83 (1.26)	39.24 (3.08)	2.60 (1.16)	-5.85 (1.55)	-94.42 (1.29)	-4.39 (2.06)
	3	-13.66 (3.03)	26.61 (2.27)	40.27 (4.75)	3.10 (2.81)	-5.89 (3.88)	-94.38 (1.76)	-6.99 (1.81)
	4	-16.71 (1.84)	23.61 (0.73)	40.32 (1.85)	2.51 (1.11)	-7.93 (1.10)	-92.24 (1.56)	-4.79 (1.06)
	5	-15.30 (2.84)	23.51 (1.51)	37.81 (4.52)	3.15 (1.96)	-5.99 (2.22)	-92.03 (2.97)	-5.13 (2.37)
	6	-13.40 (2.25)	24.72 (1.31)	37.20 (2.62)	4.03 (1.02)	-5.07 (1.65)	-91.83 (3.67)	-4.79 (1.78)
7	1	1.42 (2.26)	39.77 (0.70)	38.34 (2.06)	0.74 (1.27)	-8.20 (2.23)	-99.85 (1.38)	-3.85 (1.80)
	2	-7.62 (5.56)	38.55 (2.03)	46.18 (6.82)	0.34 (1.15)	-10.27 (1.94)	-99.97 (0.88)	-3.59 (0.77)
	3	-15.10 (6.39)	41.81 (2.12)	56.91 (7.20)	-0.85 (2.65)	-11.84 (2.73)	-102.75 (3.06)	-11.80 (3.96)
	4	-7.51 (4.63)	40.54 (0.65)	48.04 (4.60)	1.49 (1.05)	-8.26 (1.30)	-99.51 (1.32)	-4.75 (2.73)
	5	-12.70 (5.80)	41.11 (1.15)	53.75 (6.91)	0.15 (1.50)	-11.13 (2.04)	-99.79 (2.86)	-8.20 (4.01)
	6	-9.85 (1.76)	37.69 (2.15)	47.55 (3.46)	-0.46 (1.19)	-9.90 (1.85)	-99.53 (2.95)	-3.92 (1.12)
9	1	-13.01 (4.12)	32.92 (1.38)	45.92 (4.48)	-1.15 (0.88)	-5.16 (2.40)	-95.24 (1.81)	-5.61 (2.15)
	2	-13.24 (2.21)	35.27 (1.34)	47.20 (4.78)	-3.20 (0.95)	-8.73 (2.04)	-93.96 (3.03)	-7.66 (3.31)
	3	-12.45 (3.10)	36.05 (1.39)	48.46 (3.97)	-3.72 (1.28)	-9.28 (1.95)	-95.31 (2.55)	-6.02 (3.73)
	4	-14.26 (2.97)	35.68 (1.42)	49.41 (4.37)	-1.89 (0.65)	-8.39 (1.78)	-95.73 (1.25)	-5.29 (1.35)
	5	-14.49 (2.65)	35.70 (1.14)	46.89 (3.88)	-2.19 (1.16)	-7.78 (2.36)	-95.25 (1.34)	-5.58 (1.99)
	6	-14.0 (2.26)	35.82 (1.24)	49.83 (1.94)	-3.30 (0.56)	-9.69 (1.02)	-95.71 (2.34)	-6.22 (1.75)

Continued.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
11	1	-10.39 (5.16)	39.77 (1.64)	50.16 (4.80)	-6.73 (1.0)	-12.24 (2.30)	-106.37 (0.82)	-8.24 (1.70)
	2	-10.68 (3.37)	38.49 (1.24)	49.17 (4.13)	-0.56 (3.85)	-10.34 (3.57)	-103.20 (1.14)	-10.96 (0.74)
	3	-8.56 (1.03)	38.82 (2.25)	47.38 (2.90)	-5.87 (2.25)	-16.27 (2.65)	-103.77 (1.17)	-7.42 (1.33)
	4	-10.65 (2.17)	37.99 (1.85)	48.64 (2.12)	-5.71 (1.32)	-9.55 (3.73)	-105.31 (0.90)	-7.99 (1.47)
	5	-8.03 (2.84)	39.38 (1.07)	47.16 (3.46)	-6.96 (1.96)	-16.91 (3.80)	-108.82 (5.40)	-9.59 (2.80)
	6	-14.23 (3.33)	36.55 (1.87)	50.83 (4.12)	-4.74 (0.92)	-11.87 (2.32)	-106.49 (1.34)	-12.01 (2.84)
18	1	-2.55 (3.15)	29.98 (2.38)	32.53 (4.89)	2.13 (0.68)	-5.18 (1.51)	-87.42 (1.44)	-4.95 (2.57)
	2	-8.04 (1.94)	34.26 (1.23)	42.30 (2.32)	-0.50 (1.44)	-5.59 (0.97)	-90.58 (0.95)	-4.53 (1.47)
	3	-14.22 (2.73)	35.57 (1.58)	49.31 (4.11)	-0.35 (0.97)	-4.50 (1.52)	-96.15 (4.09)	-9.59 (3.99)
	4	-3.97 (6.77)	35.25 (3.83)	39.22 (5.50)	2.43 (1.98)	-3.82 (2.64)	-91.71 (1.80)	-6.53 (2.62)
	5	-6.53 (2.50)	35.17 (0.58)	40.72 (1.20)	1.72 (0.87)	-4.11 (0.41)	-90.75 (1.68)	-6.41 (2.52)
	6	-10.39 (2.42)	32.56 (0.65)	42.77 (2.83)	0.23 (2.06)	-4.85 (2.36)	-90.24 (0.85)	-6.09 (1.19)
22	1	-8.58 (1.96)	34.61 (1.86)	43.19 (3.79)	-1.71 (1.20)	-2.40 (2.04)	-96.48 (1.0)	-6.19 (1.96)
	2	-9.20 (1.74)	34.92 (1.33)	44.12 (1.11)	-3.66 (1.28)	-3.57 (1.43)	-97.36 (1.79)	-4.12 (1.60)
	3	-8.03 (1.59)	33.86 (1.50)	41.90 (1.89)	-8.22 (0.76)	-8.04 (0.72)	-100.93 (1.94)	-4.85 (0.83)
	4	-6.36 (4.59)	35.36 (1.24)	41.72 (3.83)	-2.01 (1.77)	-2.79 (1.95)	-96.90 (1.32)	-3.69 (1.98)
	5	-7.71 (2.05)	34.31 (1.67)	42.02 (1.77)	-6.64 (2.10)	-4.81 (2.33)	-99.50 (1.48)	-3.30 (1.49)
	6	-10.0 (2.04)	33.69 (1.60)	43.69 (2.22)	-8.07 (1.91)	-7.29 (1.60)	-99.91 (0.58)	-4.41 (1.38)

Continued.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
24	1	-24.19	32.79	56.98	-3.98	-6.84	-96.12	-3.99
		(1.63)	(2.80)	(4.13)	(2.0)	(2.30)	(0.92)	(1.30)
	2	-13.99	34.53	48.52	-2.74	-4.68	-98.78	-3.35
		(3.61)	(2.38)	(1.36)	(1.61)	(2.09)	(8.60)	(3.41)
	3	-18.39	33.94	52.33	-4.15	-6.36	-94.77	-2.80
		(1.48)	(0.99)	(2.23)	(0.93)	(1.75)	(1.43)	(1.46)
	4	-21.12	33.51	54.63	-4.17	-6.61	-95.99	-4.81
		(1.45)	(2.49)	(1.21)	(1.66)	(3.43)	(1.35)	(2.47)
	5	-22.83	34.53	57.37	-3.54	-7.83	-95.55	-4.65
		(2.54)	(1.42)	(1.74)	(0.64)	(1.75)	(0.72)	(1.53)
	6	-22.07	35.08	57.16	-3.31	-5.47	-95.0	-2.36
		(3.0)	(1.84)	(3.66)	(1.18)	(1.07)	(1.54)	(3.26)
25	1	-24.55	36.85	61.40	-3.45	-5.71	-105.17	-16.40
		(2.34)	(1.24)	(2.68)	(1.17)	(3.18)	(0.95)	(2.23)
	2	-20.18	36.35	56.53	-8.25	-12.30	-106.86	-16.61
		(2.59)	(0.51)	(2.19)	(3.03)	(3.13)	(1.95)	(1.78)
	3	-19.61	34.87	54.48	-11.32	-14.90	-111.10	-15.78
		(1.73)	(0.67)	(1.67)	(1.39)	(1.30)	(1.15)	(0.92)
	4	-20.09	34.83	54.92	-6.26	-8.34	-105.28	-14.49
		(5.96)	(2.38)	(6.31)	(1.69)	(3.03)	(1.91)	(2.15)
	5	-19.38	36.07	55.45	-8.01	-10.56	-108.12	-16.53
		(2.05)	(1.28)	(2.35)	(2.51)	(3.69)	(0.64)	(2.53)
	6	-21.13	36.36	57.49	-12.16	-15.41	-111.61	-17.45
		(2.85)	(0.93)	(2.17)	(3.48)	(6.14)	(2.09)	(2.67)
26	1	-17.45	32.98	50.43	-7.76	-17.41	-109.29	-15.45
		(0.72)	(1.30)	(1.43)	(1.18)	(2.91)	(1.24)	(1.11)
	2	-16.17	34.63	50.80	-8.40	-17.74	-111.29	-16.31
		(2.73)	(1.22)	(1.88)	(1.27)	(1.06)	(0.62)	(2.77)
	3	-14.54	36.55	50.94	-8.54	-18.69	-114.21	-17.02
		(2.08)	(1.77)	(2.48)	(1.29)	(1.21)	(4.18)	(5.32)
	4	-16.63	33.50	48.87	-4.70	-13.41	-107.53	-13.13
		(4.91)	(0.38)	(3.59)	(2.14)	(4.0)	(1.12)	(1.43)
	5	-14.86	35.58	50.44	-9.13	-15.12	-112.03	-18.05
		(3.57)	(1.69)	(2.50)	(1.07)	(8.45)	(1.75)	(6.36)
	6	-12.56	35.31	47.87	-11.24	-18.56	-111.69	-16.57
		(12.88)	(1.29)	(12.24)	(3.38)	(7.32)	(1.17)	(4.29)

Continued.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
27	1	-12.13	35.02	47.15	-3.76	-15.19	-110.90	-10.20
		(0.66)	(4.14)	(4.06)	(0.84)	(0.93)	(1.40)	(1.67)
	2	-9.99	31.50	41.50	-2.94	-13.96	-107.61	-7.47
		(1.58)	(2.89)	(3.92)	(1.61)	(1.79)	(1.02)	(1.44)
	3	-16.08	34.47	50.55	-4.94	-16.03	-110.43	-7.91
		(5.63)	(1.58)	(6.13)	(1.28)	(1.57)	(1.65)	(2.91)
	4	-7.47	26.02	33.49	-0.47	-10.78	-104.49	-6.44
		(1.32)	(2.66)	(2.52)	(1.39)	(1.17)	(1.18)	(1.04)
	5	-7.10	33.13	40.23	-3.49	-12.05	-108.30	-8.05
		(2.94)	(3.57)	(5.10)	(0.90)	(0.59)	(1.17)	(1.52)
	6	-8.14	34.35	42.49	-4.94	-15.35	-108.43	-8.35
		(1.16)	(2.91)	(2.41)	(2.27)	(2.32)	(1.38)	(1.34)
28	1	-19.09	35.04	54.13	2.03	-1.16	-89.39	-9.41
		(1.94)	(0.37)	(2.11)	(1.47)	(2.72)	(2.32)	(1.45)
	2	-24.70	32.27	56.97	1.92	2.37	-90.59	-9.33
		(1.12)	(1.22)	(1.84)	(2.27)	(3.05)	(1.82)	(1.31)
	3	-20.51	34.17	54.68	-0.88	-2.06	-94.24	-12.86
		(2.90)	(1.04)	(2.70)	(2.72)	(1.74)	(3.27)	(4.09)
	4	-21.92	34.60	55.58	2.06	2.34	-87.88	-7.83
		(3.79)	(0.83)	(4.85)	(1.21)	(1.88)	(1.51)	(0.65)
	5	-20.72	34.62	55.34	0.16	-1.57	-92.33	-10.98
		(2.46)	(1.43)	(3.52)	(1.94)	(2.09)	(2.73)	(2.14)
	6	-21.09	34.13	55.22	-0.55	0.11	-89.72	-25.20
		(12.15)	(1.19)	(11.97)	(2.41)	(0.94)	(2.46)	(35.70)
29	1	-10.50	35.47	45.97	-0.41	-12.45	-95.25	-7.19
		(2.21)	(3.28)	(4.38)	(1.44)	(1.42)	(1.19)	(1.73)
	2	-11.66	36.24	47.90	-1.72	-17.59	-103.19	-13.69
		(2.77)	(2.31)	(2.55)	(1.70)	(4.26)	(7.42)	(4.92)
	3	-15.62	36.71	52.33	-3.85	-14.05	-98.50	-9.55
		(2.21)	(3.10)	(3.79)	(2.27)	(2.04)	(0.36)	(1.10)
	4	-15.97	35.48	51.45	-0.15	-11.08	-98.08	-9.74
		(2.10)	(1.61)	(1.17)	(0.93)	(1.25)	(1.95)	(1.90)
	5	-15.29	40.26	55.54	-2.99	-13.60	-98.12	-9.42
		(3.11)	(0.99)	(3.18)	(1.81)	(2.34)	(1.08)	(1.20)
	6	-14.23	40.33	54.56	-2.44	-12.40	-101.47	-11.0
		(2.67)	(1.91)	(2.94)	(0.79)	(3.44)	(3.71)	(2.82)

Continued.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
31	1	-9.11	34.65	43.59	2.03	-9.25	-118.37	-9.02
		(4.53)	(8.15)	(9.0)	(2.13)	(2.42)	(8.72)	(8.89)
	2	-8.18	35.88	40.47	-2.11	-10.13	-111.69	-26.35
		(5.43)	(3.78)	(5.77)	(3.73)	(6.23)	(1.73)	(47.51)
	3	-9.96	34.55	44.50	-0.64	-9.28	-111.45	-3.17
		(2.90)	(2.47)	(5.01)	(2.82)	(3.22)	(0.81)	(2.94)
	4	-9.37	35.37	40.74	0.94	-13.06	-113.85	-5.04
		(3.36)	(1.03)	(7.89)	(1.98)	(2.20)	(2.65)	(2.49)
	5	-5.57	41.66	35.19	-9.13	-15.82	-115.40	-2.98
		(4.91)	(5.54)	(13.02)	(3.81)	(5.06)	(6.82)	(11.76)
	6	-5.63	34.12	39.27	-2.28	-11.16	-111.38	-4.0
		(2.15)	(1.38)	(2.84)	(2.22)	(3.76)	(0.88)	(1.29)
32	1	-19.15	27.86	47.01	-12.99	-20.32	-103.14	-7.25
		(2.77)	(1.86)	(4.08)	(1.68)	(2.73)	(0.64)	(1.50)
	2	-18.24	28.63	45.58	-13.76	-23.01	-104.06	-6.53
		(2.14)	(1.01)	(3.35)	(1.66)	(1.02)	(1.20)	(2.85)
	3	-19.08	27.42	46.03	-11.26	-22.74	-104.50	-7.64
		(1.0)	(0.75)	(1.92)	(2.03)	(2.27)	(0.83)	(0.78)
	4	-18.61	29.05	47.66	-13.19	-21.31	-103.58	-6.51
		(2.27)	(0.66)	(2.35)	(1.32)	(2.03)	(1.07)	(1.01)
	5	-18.50	28.67	45.68	-12.86	-19.18	-103.19	-6.04
		(2.47)	(1.26)	(2.89)	(2.16)	(2.03)	(0.75)	(2.61)
	6	-16.52	28.32	44.29	-12.10	-22.65	-103.55	-7.37
		(1.91)	(0.84)	(1.92)	(1.07)	(1.11)	(1.10)	(0.33)
33	1	-22.67	27.64	50.31	-94.35	-8.67	-94.35	-8.67
		(3.30)	(2.77)	(5.26)	(1.89)	(2.12)	(1.89)	(2.12)
	2	-22.68	40.26	62.94	-94.07	-4.20	-94.07	-4.20
		(3.06)	(2.19)	(4.30)	(1.14)	(1.23)	(1.14)	(1.23)
	3	-20.80	39.75	60.55	-2.47	-6.86	-96.82	-7.56
		-20.34	39.72	60.06	-1.59	-5.96	1.89	1.13
	4	-20.34	39.72	60.06	-1.59	-5.96	-94.85	-3.59
		(2.07)	(1.64)	(1.90)	(1.85)	(2.41)	(0.97)	(2.20)
	5	-20.43	38.41	58.84	-3.22	-6.18	-97.05	-6.36
		(1.12)	(1.42)	(1.51)	(1.46)	(1.97)	(1.55)	(1.06)
	6	-22.76	36.29	59.18	-2.87	-3.34	-96.67	-8.42
		(2.28)	(2.58)	(1.48)	(1.65)	(3.22)	(1.20)	(1.28)

Continued.

Subj	Cond	Contact	DF	DF ROM	Abd	Abduction ROM	External Rotation	Ext Rotat ROM
35	1	-21.97 (1.95)	29.87 (1.24)	50.82 (2.92)	-5.83 (1.37)	-12.58 (3.09)	-92.90 (1.62)	-8.34 (3.13)
	2	-23.09 (1.71)	30.52 (2.17)	52.54 (3.17)	-8.07 (1.79)	-16.44 (4.10)	-100.13 (10.25)	-15.51 (7.84)
	3	-19.21 (2.70)	28.49 (1.47)	44.53 (4.01)	-4.83 (2.92)	-13.45 (2.50)	-94.18 (6.79)	-8.22 (4.96)
	4	-21.98 (2.74)	32.08 (1.25)	54.26 (3.46)	-8.58 (1.76)	-16.04 (1.55)	-98.17 (10.51)	-8.24 (1.57)
	5	-24.06 (2.14)	32.77 (9.85)	55.43 (11.12)	-5.71 (2.45)	-12.94 (5.32)	-102.29 (16.27)	-11.53 (16.80)
	6	-10.91 (13.93)	24.73 (6.79)	33.32 (25.40)	-7.57 (7.25)	-10.14 (10.10)	-97.73 (4.82)	-7.51 (5.77)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AB

Male Subject Table Right Ankle Angular Velocity Data

Male subject right ankle angular velocity data.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
2	1	524.30	789.03	-162.85	-75.68
		(61.64)	(29.24)	(87.60)	(17.20)
	2	543.41	833.44	-152.70	-59.70
		(38.69)	(30.50)	(32.37)	(22.52)
	3	654.93	939.28	-202.07	-85.31
		(102.01)	(29.64)	(84.60)	(32.92)
	4	421.29	756.13	-171.69	-81.57
		(57.81)	(26.47)	(22.92)	(22.65)
	5	560.35	818.68	-193.32	-86.13
		(60.82)	(53.93)	(43.31)	(23.83)
	6	674.15	870.25	-210.49	-79.33
		(89.70)	(45.18)	(28.09)	(24.97)
7	1	453.61	646.03	-156.43	-38.37
		(71.96)	(51.47)	(68.16)	(12.12)
	2	477.60	792.99	-154.44	-65.16
		(41.96)	(113.01)	(25.63)	(17.59)
	3	425.98	1031.29	-278.38	-196.88
		(259.24)	(262.19)	(66.44)	(241.64)
	4	386.26	704.41	-188.48	-32.98
		(63.72)	(62.70)	(46.67)	(13.19)
	5	410.18	830.18	-253.73	-101.40
		(87.72)	(57.48)	(75.16)	(37.78)
	6	622.33	869.35	-170.91	-83.37
		(62.63)	(55.15)	(26.35)	(10.48)
9	1	524.19	839.82	-144.07	-94.60
		(103.48)	(35.72)	(58.49)	(22.76)
	2	660.20	954.67	-195.85	-62.09
		(46.79)	(39.02)	(18.25)	(30.20)
	3	677.56	949.86	-228.47	-62.40
		(157.41)	(63.47)	(32.50)	(34.84)
	4	522.15	882.23	-218.61	-145.47
		(19.96)	(70.72)	(30.25)	(79.06)
	5	609.40	939.50	-214.65	-140.59
		(120.28)	(68.34)	(37.08)	(47.36)
	6	697.89	1006.04	-261.33	-153.79
		(72.27)	(58.33)	(38.73)	(74.61)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
11	1	467.60	846.84	-163.53	-142.74
		(107.18)	(76.0)	(37.35)	(22.80)
	2	626.93	896.20	-206.47	-109.29
		(53.86)	(68.15)	(37.01)	(20.46)
	3	796.29	992.02	-262.93	-78.74
		(61.52)	(40.45)	(54.63)	(30.93)
	4	492.19	823.17	-122.79	-112.63
		(59.09)	(11.21)	(43.03)	(15.91)
	5	731.53	960.73	-127.65	-109.77
		(137.97)	(184.19)	(130.74)	(47.13)
	6	591.75	937.39	-200.69	-189.31
		(194.40)	(90.19)	(27.0)	(105.09)
18	1	298.68	527.27	-193.50	-60.73
		(82.03)	(85.04)	(68.89)	(41.83)
	2	582.23	776.52	-177.96	-57.80
		(35.30)	(50.97)	(34.80)	(26.14)
	3	514.52	950.05	-255.82	-231.42
		(299.80)	(244.34)	(100.30)	(203.36)
	4	315.57	618.92	-204.60	-108.59
		(92.38)	(75.47)	(66.98)	(56.58)
	5	401.57	681.24	-193.09	-108.98
		(39.66)	(89.09)	(36.97)	(44.06)
	6	449.14	750.32	-217.13	-80.93
		(123.47)	(60.72)	(58.75)	(33.37)
22	1	470.62	665.19	-133.99	-78.74
		(31.94)	(25.30)	(20.09)	(31.99)
	2	524.88	808.72	-67.36	-68.82
		(56.25)	(33.27)	(36.62)	(38.80)
	3	595.06	810.11	-54.79	-53.95
		(60.35)	(22.56)	(41.08)	(23.79)
	4	465.14	701.73	-60.99	-68.43
		(57.70)	(29.61)	(53.96)	(23.08)
	5	558.89	792.78	-46.31	-53.78
		(58.10)	(12.77)	(30.85)	(12.70)
	6	600.27	838.20	-40.73	-68.03
		(60.10)	(28.22)	(17.35)	(30.80)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
24	1	370.02 (64.94)	832.76 (12.05)	-80.13 (38.43)	-71.50 (17.17)
	2	596.49 (169.86)	948.38 (237.33)	-152.68 (174.61)	-187.20 (250.65)
	3	661.01 (93.72)	974.42 (42.57)	-78.46 (26.17)	-56.28 (11.48)
	4	311.01 (40.09)	720.20 (23.40)	-141.37 (78.67)	-47.58 (10.99)
	5	418.26 (33.67)	852.20 (25.65)	-157.39 (56.68)	-40.47 (11.29)
	6	442.45 (107.70)	918.08 (40.92)	-94.50 (41.73)	-45.67 (17.90)
25	1	520.02 (114.51)	1043.13 (57.61)	-182.15 (44.73)	-165.74 (43.97)
	2	646.97 (127.14)	1074.03 (66.54)	-164.92 (55.86)	-159.80 (34.0)
	3	651.49 (55.40)	1077.86 (33.21)	-168.65 (53.33)	-121.73 (28.05)
	4	608.79 (59.88)	1005.16 (78.23)	-151.01 (72.05)	-166.72 (27.87)
	5	645.78 (72.84)	1027.84 (43.77)	-127.42 (48.85)	-149.46 (10.07)
	6	640.97 (85.37)	1120.36 (52.67)	-226.52 (96.89)	-138.10 (24.20)
26	1	453.03 (53.13)	851.22 (97.60)	-340.10 (58.94)	-278.91 (44.94)
	2	628.77 (81.75)	1003.76 (62.25)	-421.36 (98.50)	-368.36 (147.59)
	3	739.15 (125.29)	1167.78 (350.15)	-354.11 (122.04)	-460.14 (324.30)
	4	537.88 (239.50)	1001.53 (98.19)	-245.20 (79.34)	-215.84 (55.09)
	5	802.78 (238.59)	829.95 (439.88)	-224.59 (99.48)	-304.80 (135.31)
	6	482.30 (496.76)	950.73 (705.62)	-236.07 (160.22)	-446.42 (424.18)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
27	1	447.22 (43.02)	715.53 (41.26)	-363.88 (49.77)	-108.23 (18.46)
	2	499.89 (58.18)	727.44 (40.37)	-296.15 (27.97)	-61.34 (13.49)
	3	511.97 (196.89)	848.38 (143.63)	-356.60 (85.88)	-97.04 (26.39)
	4	396.97 (58.73)	589.08 (41.63)	-201.50 (43.82)	-74.56 (27.25)
	5	448.58 (34.01)	654.72 (39.55)	-270.04 (23.80)	-83.71 (15.35)
	6	511.40 (62.96)	727.92 (24.49)	-316.33 (38.13)	-85.50 (21.49)
28	1	560.24 (41.01)	874.32 (32.21)	-112.59 (31.94)	-197.02 (37.39)
	2	553.09 (18.45)	1053.65 (97.06)	-121.68 (26.50)	-254.13 (91.77)
	3	616.25 (189.09)	1036.91 (58.28)	-228.27 (76.63)	-151.44 (67.22)
	4	457.97 (72.45)	852.42 (73.42)	-86.25 (24.38)	-162.06 (30.12)
	5	522.84 (110.50)	941.63 (37.45)	-112.61 (29.90)	-225.70 (39.85)
	6	376.04 (281.67)	957.74 (258.06)	-144.61 (89.74)	-166.50 (150.15)
29	1	426.09 (42.66)	677.62 (33.81)	-340.79 (55.50)	-80.06 (26.20)
	2	575.95 (103.15)	901.67 (225.96)	-525.18 (128.79)	-308.93 (287.04)
	3	549.78 (64.59)	856.47 (55.04)	-432.96 (68.63)	-101.66 (35.66)
	4	484.90 (26.76)	755.34 (37.74)	-399.27 (39.58)	-79.61 (18.15)
	5	559.69 (94.79)	831.87 (97.61)	-401.60 (65.02)	-101.92 (28.28)
	6	561.98 (85.11)	857.09 (156.97)	-458.76 (90.88)	-95.27 (9.70)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
31	1	374.88 (69.96)	788.54 (278.71)	-243.60 (74.07)	-283.56 (271.99)
	2	431.46 (253.67)	916.83 (113.32)	-246.29 (156.61)	-91.49 (76.25)
	3	537.64 (115.57)	869.42 (74.98)	-161.38 (23.23)	-57.97 (46.77)
	4	435.94 (47.61)	835.64 (178.11)	-235.44 (76.39)	-151.47 (95.33)
	5	830.14 (131.37)	1242.33 (205.46)	-360.47 (212.78)	-339.41 (176.23)
	6	695.75 (66.36)	850.75 (49.07)	-150.58 (38.63)	-71.17 (34.43)
32	1	353.54 (100.44)	766.97 (43.47)	-284.63 (52.64)	-139.26 (14.47)
	2	535.20 (53.51)	872.61 (20.04)	-259.09 (48.25)	-107.04 (27.78)
	3	533.06 (34.90)	868.14 (38.26)	-332.52 (25.55)	-74.0 (17.84)
	4	489.64 (60.99)	847.01 (52.62)	-255.32 (43.19)	-103.38 (42.86)
	5	562.40 (78.91)	942.58 (69.38)	-259.13 (40.85)	-105.23 (35.55)
	6	593.60 (49.29)	894.17 (31.87)	-319.47 (33.19)	-88.21 (25.76)
33	1	446.20 (91.65)	793.55 (18.14)	-96.25 (15.90)	-96.25 (15.90)
	2	599.36 (94.02)	1034.26 (39.09)	-112.47 (23.69)	-112.47 (23.69)
	3	724.16 444.12	1118.25 873.30	-173.19 -190.03	-145.39 41.35
	4	444.12 (33.25)	873.30 (17.85)	-190.03 (47.13)	-88.66 (19.41)
	5	615.60 (56.92)	1006.38 (29.30)	-196.0 (22.02)	-121.27 (25.42)
	6	768.96 (113.85)	1141.81 (42.07)	-195.19 (36.93)	-160.28 (13.94)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
35	1	497.76	803.39	-391.25	-41.85
		(23.39)	(34.02)	(81.75)	(23.38)
	2	498.44	988.39	-547.28	-329.12
		(44.56)	(228.67)	(95.94)	(379.77)
	3	595.12	865.66	-603.40	-172.42
		(87.65)	(186.09)	(13.31)	(217.50)
	4	472.25	894.53	-455.76	-199.46
		(113.29)	(264.44)	(94.13)	(350.29)
	5	529.92	1118.95	-536.89	-452.75
		(94.21)	(368.40)	(85.40)	(448.84)
	6	506.37	685.62	-472.93	-167.19
		(295.58)	(383.52)	(261.88)	(161.53)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AC

Male Subject Table Right Knee Angle Data

Male subject right knee angle data.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
2	1	-16.28	-63.43	-47.15	7.37	4.43	-4.82	4.17
		(1.22)	(4.63)	(5.45)	(2.58)	(2.40)	(1.92)	(1.61)
	2	-20.64	-78.12	-57.48	11.05	2.54	-0.20	6.61
		(1.01)	(5.11)	(4.25)	(1.42)	(2.66)	(3.03)	(3.45)
	3	-25.08	-96.22	-71.13	10.76	6.67	0.10	10.37
		(2.76)	(5.85)	(4.58)	(0.79)	(1.39)	(2.13)	(1.66)
	4	-15.65	-54.91	-39.26	5.69	1.32	-5.50	4.52
		(1.22)	(2.69)	(2.98)	(0.61)	(2.24)	(1.77)	(2.12)
	5	-16.96	-68.20	-51.24	8.50	4.48	-5.94	4.20
		(1.38)	(2.09)	(3.22)	(1.03)	(1.19)	(1.50)	(1.74)
	6	-21.69	-84.43	-62.73	10.41	7.34	-3.52	6.04
		(3.29)	(7.53)	(6.74)	(1.08)	(0.46)	(2.21)	(3.59)
7	1	-27.12	-92.17	-65.03	4.94	3.36	-6.45	3.18
		(3.59)	(8.02)	(5.58)	(1.40)	(1.02)	(1.09)	(2.11)
	2	-27.63	-95.21	-67.59	6.27	4.90	-2.58	4.33
		(3.16)	(4.27)	(6.13)	(1.04)	(1.56)	(3.09)	(1.08)
	3	-25.30	-112.65	-87.79	8.55	6.53	-2.17	7.62
		(2.05)	(5.52)	(4.78)	(1.68)	(2.99)	(2.64)	(1.76)
	4	-27.41	-99.41	-72.16	5.32	3.29	-7.34	3.77
		(3.16)	(4.28)	(4.42)	(1.49)	(2.12)	(1.76)	(2.04)
	5	-25.11	-99.72	-74.67	6.37	4.11	-6.58	6.11
		(1.76)	(3.90)	(3.57)	(1.68)	(2.48)	(1.34)	(2.13)
	6	-26.15	-106.35	-80.20	6.22	3.59	-0.76	5.67
		(2.41)	(4.09)	(4.09)	(0.88)	(0.87)	(4.04)	(4.53)
9	1	-22.57	-85.33	-62.76	8.86	5.62	-2.0	6.79
		(2.22)	(11.09)	(9.54)	(1.90)	(2.14)	(0.59)	(1.12)
	2	-26.54	-95.99	-69.46	8.73	5.62	-0.32	6.33
		(0.78)	(1.16)	(1.05)	(2.40)	(2.95)	(1.10)	(2.20)
	3	-26.86	-102.86	-76.0	9.49	6.40	0.20	5.60
		(1.92)	(7.94)	(7.58)	(1.31)	(0.92)	(1.68)	(0.90)
	4	-23.02	-84.69	-61.66	9.23	5.62	-1.89	7.08
		(1.63)	(4.98)	(4.08)	(1.06)	(1.52)	(0.40)	(0.92)
	5	-23.37	-89.58	-66.21	8.61	5.07	-1.59	8.80
		(1.16)	(8.58)	(8.12)	(1.31)	(1.33)	(0.60)	(1.03)
	6	-25.91	-101.59	-75.68	9.42	5.72	0.16	8.14
		(0.78)	(8.62)	(8.02)	(1.44)	(1.46)	(1.39)	(2.54)

Continued.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
11	1	-26.37	-98.46	-72.08	16.01	12.02	10.42	19.31
		(2.30)	(5.65)	(3.85)	(0.48)	(0.91)	(1.02)	(1.15)
	2	-17.87	-102.05	-84.41	14.03	9.51	7.38	-17.59
		(17.57)	(4.40)	(16.69)	(1.43)	(4.95)	(2.02)	(80.46)
	3	-27.64	-121.76	-94.12	16.22	12.30	17.79	23.69
		(1.38)	(3.49)	(3.64)	(0.68)	(0.85)	(2.40)	(1.59)
	4	-23.99	-91.31	-67.06	16.85	13.23	10.03	18.39
		(2.38)	(6.10)	(6.19)	(1.26)	(1.75)	(2.68)	(2.44)
	5	-24.12	-106.95	-82.97	16.89	13.23	12.48	21.98
		(2.34)	(7.33)	(9.09)	(1.53)	(1.36)	(1.94)	(2.88)
	6	-24.50	-104.35	-79.82	15.91	12.81	12.58	19.25
		(1.06)	(3.67)	(2.96)	(0.81)	(0.56)	(1.36)	(1.38)
18	1	-30.88	-73.49	-42.61	9.35	5.21	-0.75	5.60
		(2.15)	(7.61)	(5.93)	(1.58)	(0.66)	(1.08)	(2.35)
	2	-29.26	-93.33	-64.07	14.61	10.95	1.54	11.79
		(1.29)	(4.29)	(4.04)	(0.91)	(1.39)	(1.21)	(0.98)
	3	-28.86	-93.86	-65.0	14.87	10.42	1.72	10.26
		(1.95)	(5.72)	(4.93)	(1.29)	(4.62)	(1.75)	(2.46)
	4	-29.92	-79.87	-49.95	15.46	10.67	-2.62	8.52
		(1.04)	(6.62)	(6.53)	(3.19)	(2.42)	(0.98)	(3.17)
	5	-27.61	-84.64	-57.03	14.83	10.85	-2.25	8.89
		(0.92)	(2.75)	(2.45)	(1.16)	(1.15)	(0.72)	(1.69)
	6	-28.28	-87.74	-59.46	12.37	9.41	0.31	6.24
		(1.44)	(3.13)	(3.09)	(0.41)	(0.72)	(0.99)	(1.98)
22	1	-23.70	-84.57	-60.88	12.70	5.21	0.92	14.63
		(2.80)	(5.12)	(6.79)	(0.78)	(1.0)	(1.69)	(3.63)
	2	-31.82	-100.04	-68.23	12.35	4.84	9.32	13.72
		(1.47)	(3.21)	(2.54)	(1.42)	(1.02)	(1.61)	(2.06)
	3	-33.56	-100.06	-66.51	10.06	1.51	14.99	12.38
		(1.65)	(5.02)	(4.84)	(0.77)	(0.77)	(0.94)	(2.41)
	4	-29.95	-94.54	-64.59	14.04	5.43	5.68	17.12
		(4.21)	(2.56)	(4.56)	(0.51)	(1.13)	(0.59)	(2.18)
	5	-31.25	-100.59	-69.34	10.87	1.87	14.55	15.27
		(1.94)	(7.42)	(6.05)	(0.77)	(0.79)	(1.01)	(1.89)
	6	-31.01	-101.20	-70.19	10.11	0.58	16.60	16.13
		(3.63)	(8.26)	(7.13)	(1.31)	(1.17)	(1.0)	(2.02)

Continued.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
24	1	-21.13 (2.64)	-77.63 (9.44)	-56.50 (8.84)	12.59 (2.29)	8.73 (2.39)	2.99 (2.58)	11.58 (1.57)
	2	-31.59 (3.28)	-97.48 (4.46)	-65.89 (2.24)	11.37 (0.64)	7.97 (0.94)	7.05 (0.77)	13.36 (1.38)
	3	-31.40 (1.32)	-113.84 (7.82)	-82.44 (7.77)	14.43 (1.23)	9.21 (1.45)	11.39 (1.42)	18.04 (2.04)
	4	-22.87 (3.0)	-78.59 (7.75)	-55.72 (5.70)	11.85 (0.99)	7.44 (1.73)	2.34 (1.24)	10.34 (1.67)
	5	-23.37 (1.48)	-79.87 (5.29)	-56.50 (4.70)	12.84 (0.66)	8.69 (1.02)	3.87 (1.0)	11.56 (1.38)
	6	-28.49 (1.76)	-97.65 (6.61)	-69.16 (5.48)	11.74 (1.13)	7.26 (0.86)	7.0 (1.12)	11.76 (1.54)
25	1	-21.56 (1.99)	-82.56 (3.40)	-61.0 (2.87)	5.24 (1.77)	2.30 (1.61)	6.70 (0.88)	9.18 (2.74)
	2	-26.76 (1.26)	-98.20 (2.38)	-71.44 (1.74)	5.42 (0.66)	1.75 (0.76)	9.56 (0.79)	10.50 (1.04)
	3	-31.50 (1.84)	-117.71 (2.38)	-86.21 (0.99)	8.09 (1.04)	2.83 (1.57)	10.35 (0.77)	10.74 (1.55)
	4	-24.96 (2.31)	-81.17 (4.09)	-56.22 (5.62)	4.32 (1.92)	1.58 (1.48)	10.54 (1.01)	8.11 (1.70)
	5	-27.43 (1.84)	-99.86 (4.76)	-72.43 (4.52)	5.45 (1.41)	1.86 (1.23)	9.44 (1.37)	9.33 (1.78)
	6	-34.27 (1.26)	-120.03 (3.27)	-85.76 (4.16)	7.29 (0.78)	2.22 (0.90)	11.11 (1.79)	11.65 (1.46)
26	1	-16.09 (1.44)	-57.96 (2.11)	-41.88 (2.72)	14.33 (1.24)	2.24 (0.74)	22.69 (1.48)	20.79 (1.85)
	2	-27.90 (1.78)	-77.75 (2.68)	-49.85 (1.12)	15.07 (0.74)	1.61 (1.08)	25.54 (0.91)	23.98 (2.25)
	3	-30.65 (2.45)	-87.31 (1.76)	-56.66 (1.93)	15.0 (1.43)	3.94 (1.62)	23.95 (0.91)	21.78 (1.84)
	4	-25.16 (1.38)	-71.73 (2.90)	-46.29 (3.70)	11.58 (1.10)	2.66 (1.15)	19.19 (1.33)	20.78 (1.75)
	5	-24.34 (2.45)	-77.99 (1.45)	-53.65 (1.58)	14.80 (1.60)	3.28 (1.68)	25.64 (1.68)	22.73 (2.76)
	6	-30.75 (1.45)	-87.11 (2.73)	-56.36 (2.45)	16.38 (1.85)	5.70 (2.29)	25.30 (0.68)	21.75 (1.50)

Continued.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
27	1	-28.22	-85.44	-57.23	9.78	1.41	2.85	12.58
		(1.87)	(1.18)	(2.06)	(1.70)	(1.26)	(0.95)	(1.04)
	2	-26.28	-87.24	-60.95	8.52	1.43	4.60	13.08
		(1.13)	(8.45)	(7.95)	(1.13)	(1.17)	(1.48)	(2.70)
	3	-29.68	-99.97	-70.30	10.76	1.46	4.17	14.24
		(1.14)	(2.68)	(2.70)	(1.44)	(1.08)	(1.23)	(1.57)
	4	-23.13	-61.95	-38.82	6.21	1.51	1.84	10.92
		(2.36)	(0.54)	(2.16)	(0.98)	(0.65)	(1.52)	(0.64)
	5	-24.29	-86.05	-61.76	8.34	2.06	3.70	13.55
		(0.42)	(3.78)	(3.88)	(1.39)	(1.38)	(1.35)	(2.22)
	6	-28.52	-92.73	-64.21	8.34	1.51	4.66	12.95
		(1.86)	(7.92)	(6.44)	(1.62)	(1.62)	(1.05)	(0.76)
28	1	-23.66	-82.64	-58.99	8.71	-3.23	6.15	12.45
		(1.92)	(4.38)	(4.65)	(1.31)	(1.50)	(0.46)	(2.10)
	2	-29.51	-82.97	-53.46	4.36	-3.57	8.04	10.52
		(2.06)	(4.62)	(4.09)	(1.74)	(1.52)	(1.07)	(1.98)
	3	-31.80	-96.86	-65.06	1.28	-3.57	7.67	9.71
		(3.63)	(6.27)	(8.28)	(2.17)	(2.01)	(1.44)	(0.93)
	4	-23.29	-77.08	-53.78	6.59	-4.01	6.29	9.53
		(2.61)	(4.03)	(1.90)	(1.95)	(1.05)	(0.74)	(2.04)
	5	-26.59	-84.96	-58.36	7.18	-4.36	5.60	11.91
		(0.75)	(4.27)	(4.66)	(1.89)	(0.89)	(1.30)	(0.54)
	6	-29.02	-88.51	-59.49	5.82	-2.60	7.92	13.01
		(1.37)	(5.57)	(4.27)	(1.58)	(1.92)	(0.74)	(0.85)
29	1	-27.97	-94.39	-66.42	17.44	7.76	10.75	25.17
		(4.02)	(8.67)	(9.07)	(1.18)	(2.18)	(2.59)	(2.56)
	2	-24.42	-95.55	-71.12	18.76	9.03	11.63	26.49
		(4.0)	(5.09)	(3.03)	(0.55)	(1.48)	(1.69)	(1.74)
	3	-31.57	-113.94	-82.38	18.96	5.23	20.61	31.69
		(1.68)	(3.28)	(3.28)	(0.45)	(0.46)	(2.67)	(2.50)
	4	-23.86	-82.72	-58.86	19.21	7.82	9.80	22.78
		(3.10)	(6.97)	(5.27)	(1.58)	(2.39)	(2.52)	(1.84)
	5	-29.07	-114.21	-85.15	18.27	5.77	19.65	31.44
		(2.38)	(1.92)	(2.51)	(1.16)	(1.77)	(1.18)	(2.28)
	6	-27.58	-117.59	-90.01	17.83	5.0	20.47	32.89
		(3.74)	(4.63)	(2.93)	(1.01)	(0.67)	(1.83)	(2.99)

Continued.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
31	1	-23.57	-72.38	-48.81	19.20	8.23	1.60	11.44
		(4.79)	(11.35)	(7.41)	(3.27)	(4.46)	(3.75)	(7.51)
	2	-27.84	-84.13	-56.30	20.09	9.90	5.33	17.92
		(3.11)	(4.19)	(4.68)	(1.65)	(1.27)	(2.27)	(1.44)
	3	-30.72	-92.21	-61.49	21.49	9.25	9.11	21.55
		(2.55)	(5.97)	(5.17)	(0.57)	(1.45)	(1.10)	(2.05)
	4	-28.51	-81.05	-52.54	21.52	11.28	2.87	16.98
		(1.78)	(1.64)	(2.02)	(1.41)	(1.39)	(1.28)	(3.39)
	5	-32.84	-93.56	-53.04	24.27	11.73	7.56	18.05
		(3.66)	(4.21)	(21.34)	(6.33)	(6.32)	(2.84)	(3.73)
	6	-31.36	-101.88	-70.51	24.15	11.25	13.59	27.61
		(0.75)	(6.30)	(6.22)	(0.60)	(0.76)	(2.16)	(2.81)
32	1	-12.49	-64.81	-52.32	23.98	13.34	13.43	16.56
		(2.16)	(4.66)	(5.52)	(2.80)	(2.74)	(1.65)	(4.79)
	2	-15.86	-78.90	-63.04	25.87	16.19	18.78	21.95
		(2.44)	(5.38)	(4.76)	(0.59)	(0.84)	(2.20)	(2.71)
	3	-17.30	-89.47	-72.17	29.86	20.23	23.90	25.48
		(2.01)	(4.97)	(5.35)	(0.79)	(0.56)	(2.89)	(3.08)
	4	-16.14	-83.72	-67.57	28.25	17.88	21.30	24.96
		(1.75)	(2.35)	(3.94)	(1.07)	(0.59)	(1.63)	(2.07)
	5	-19.12	-97.83	-78.71	30.92	19.61	28.13	30.40
		(3.61)	(4.18)	(2.17)	(0.58)	(2.39)	(3.59)	(2.78)
	6	-18.02	-95.86	-77.84	31.79	21.52	27.62	30.12
		(2.78)	(6.63)	(8.77)	(1.0)	(1.48)	(3.85)	(5.62)
33	1	-18.42	-59.80	-41.39	-2.37	12.03	-2.37	12.03
		(0.63)	(1.70)	(1.61)	(0.40)	(0.70)	(0.40)	(0.70)
	2	-23.99	-87.84	-63.85	3.60	12.58	3.60	12.58
		(2.22)	(4.12)	(2.27)	(0.87)	(1.83)	(0.87)	(1.83)
	3	-24.46	-94.35	-69.89	6.39	-2.01	5.27	12.84
		-23.82	-86.54	-62.73	7.05	-3.37	0.70	1.42
	4	-23.82	-86.54	-62.73	7.05	-3.37	2.40	12.51
		(3.05)	(3.86)	(3.07)	(2.88)	(2.43)	(1.17)	(0.80)
	5	-24.01	-88.82	-64.80	5.97	-3.19	4.46	12.53
		(1.82)	(2.62)	(2.23)	(2.18)	(2.14)	(0.70)	(1.64)
	6	-25.74	-87.97	-62.23	8.54	-0.61	6.22	10.64
		(1.79)	(4.02)	(2.88)	(3.0)	(2.99)	(1.48)	(2.11)

Continued.

Subj	Cond	Contact	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Int Rotation ROM
35	1	-17.80	-102.98	-84.79	13.28	7.14	9.56	23.37
		(3.74)	(6.94)	(3.71)	(2.54)	(3.08)	(2.56)	(2.04)
	2	-21.93	-117.66	-95.73	13.11	4.52	13.23	26.42
		(2.25)	(5.03)	(6.42)	(1.08)	(1.19)	(2.87)	(2.93)
	3	-22.43	-118.70	-97.73	16.45	8.48	14.45	28.07
		(1.40)	(3.23)	(3.95)	(2.30)	(1.96)	(3.05)	(2.95)
	4	-19.78	-113.52	-93.74	11.69	4.66	11.72	25.86
		(1.95)	(2.72)	(1.56)	(1.79)	(1.51)	(1.34)	(2.10)
	5	-22.62	-118.64	-95.29	13.75	4.87	14.86	27.31
		(3.37)	(3.30)	(5.59)	(1.37)	(1.90)	(1.43)	(1.59)
	6	-27.89	-115.25	-67.21	14.55	5.34	6.0	18.06
		(5.79)	(4.71)	(50.83)	(5.44)	(5.66)	(7.49)	(9.0)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AD

Male Subject Table Right Knee Angular Velocity Data

Male subject right knee angular velocity data.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
2	1	-296.47 (23.55)	-507.14 (61.58)	57.99 (19.43)	139.28 (55.62)
	2	-330.54 (33.08)	-569.11 (41.74)	55.93 (11.13)	111.81 (27.82)
	3	-371.38 (55.55)	-712.22 (46.98)	98.52 (58.71)	88.05 (26.76)
	4	-247.65 (12.87)	-398.96 (18.24)	30.82 (8.0)	140.46 (31.90)
	5	-299.80 (34.02)	-554.05 (46.87)	50.98 (9.58)	124.39 (32.90)
	6	-398.99 (52.45)	-649.27 (40.18)	82.38 (44.12)	71.39 (42.12)
7	1	-279.88 (26.10)	-586.59 (12.56)	90.68 (34.81)	106.04 (29.61)
	2	-279.05 (27.46)	-631.46 (46.55)	128.50 (30.77)	123.20 (42.72)
	3	-319.41 (25.50)	-712.86 (20.43)	147.04 (56.89)	74.84 (33.36)
	4	-294.19 (19.76)	-516.54 (43.72)	110.15 (22.67)	111.36 (33.54)
	5	-300.97 (29.73)	-564.29 (14.37)	111.58 (29.32)	158.20 (23.24)
	6	-354.12 (21.42)	-701.47 (26.17)	155.65 (55.91)	79.54 (41.38)
9	1	-286.40 (49.38)	-540.36 (30.66)	79.04 (21.94)	169.50 (22.26)
	2	-345.33 (36.06)	-626.79 (35.15)	103.98 (16.66)	168.38 (29.44)
	3	-388.26 (43.24)	-733.39 (30.86)	128.96 (19.90)	152.80 (35.36)
	4	-287.34 (11.38)	-493.56 (27.75)	94.48 (11.84)	181.06 (7.38)
	5	-332.17 (21.92)	-573.98 (51.14)	94.95 (18.50)	170.28 (18.58)
	6	-363.14 (48.42)	-643.23 (28.92)	144.74 (14.0)	146.48 (40.52)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
11	1	-243.71 (44.11)	-549.81 (69.59)	142.95 (62.32)	80.40 (40.20)
	2	-294.06 (30.66)	-577.01 (234.71)	148.50 (46.44)	63.22 (54.08)
	3	-368.70 (42.59)	-708.0 (42.04)	208.85 (61.45)	15.38 (13.32)
	4	-218.25 (13.88)	-529.57 (31.42)	165.94 (65.07)	79.53 (14.73)
	5	-323.69 (46.28)	-616.65 (91.10)	196.73 (42.61)	45.04 (38.50)
	6	-303.93 (29.58)	-726.72 (65.06)	195.38 (20.51)	26.53 (22.43)
18	1	-170.96 (31.28)	-444.41 (37.88)	121.63 (29.15)	134.98 (58.32)
	2	-284.58 (22.82)	-632.45 (44.73)	189.76 (33.07)	143.87 (28.27)
	3	-290.51 (35.88)	-675.34 (42.09)	233.47 (59.23)	159.40 (52.19)
	4	-179.24 (35.36)	-462.64 (88.73)	147.79 (20.86)	158.84 (23.80)
	5	-219.88 (37.69)	-573.28 (32.75)	154.21 (22.46)	172.27 (32.55)
	6	-251.63 (45.62)	-582.27 (54.29)	177.20 (23.45)	104.65 (53.90)
22	1	-395.47 (65.97)	-565.30 (56.77)	81.52 (21.96)	160.48 (32.60)
	2	-457.91 (21.81)	-560.03 (24.69)	110.46 (23.04)	71.94 (68.28)
	3	-510.66 (47.17)	-595.62 (17.27)	82.63 (31.31)	31.42 (15.28)
	4	-406.32 (64.28)	-575.75 (44.57)	70.82 (23.02)	92.44 (46.15)
	5	-446.13 (42.32)	-595.70 (35.02)	91.78 (24.49)	106.19 (82.02)
	6	-507.04 (40.79)	-621.26 (43.17)	96.13 (13.22)	140.43 (96.83)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
24	1	-246.84 (32.92)	-439.22 (35.70)	80.49 (22.01)	155.91 (40.77)
	2	-276.57 (68.42)	-630.90 (22.45)	253.21 (38.45)	182.05 (16.74)
	3	-347.31 (43.77)	-745.46 (25.73)	255.51 (40.23)	202.61 (30.0)
	4	-202.56 (35.36)	-401.97 (18.71)	82.80 (16.82)	141.14 (28.51)
	5	-265.22 (19.90)	-452.28 (19.55)	101.35 (22.80)	197.04 (16.27)
	6	-269.49 (47.09)	-553.99 (36.51)	171.33 (22.29)	165.58 (28.51)
25	1	-341.27 (33.03)	-538.72 (17.19)	131.77 (17.68)	93.31 (37.93)
	2	-401.77 (20.23)	-603.24 (30.16)	101.23 (31.16)	122.05 (17.55)
	3	-419.93 (32.70)	-646.91 (24.82)	104.57 (18.76)	98.34 (25.63)
	4	-348.31 (37.77)	-512.95 (22.32)	119.21 (46.0)	134.41 (47.63)
	5	-412.20 (18.43)	-613.15 (32.07)	74.15 (26.64)	91.73 (31.18)
	6	-438.30 (64.04)	-642.03 (29.44)	105.61 (28.93)	97.0 (15.83)
26	1	-206.76 (22.24)	-451.20 (36.39)	159.53 (11.78)	261.21 (30.75)
	2	-248.95 (60.27)	-551.60 (53.90)	257.32 (49.16)	379.69 (159.92)
	3	-301.83 (112.42)	-704.96 (89.61)	223.99 (41.79)	330.06 (38.74)
	4	-204.61 (50.79)	-586.04 (52.41)	158.80 (57.46)	242.10 (41.08)
	5	-295.48 (35.47)	-633.34 (56.28)	223.47 (53.83)	356.15 (50.86)
	6	-302.33 (95.66)	-717.18 (103.55)	230.63 (19.03)	327.47 (58.25)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
27	1	-304.22 (24.73)	-512.32 (30.93)	117.74 (14.26)	128.76 (20.36)
	2	-309.61 (19.21)	-611.61 (30.72)	136.20 (18.14)	103.64 (41.14)
	3	-294.66 (73.42)	-699.40 (90.50)	128.51 (50.04)	163.81 (42.95)
	4	-224.99 (15.61)	-449.49 (27.49)	60.94 (21.60)	102.21 (24.51)
	5	-307.84 (33.04)	-610.69 (47.37)	91.71 (22.77)	101.95 (47.02)
	6	-320.79 (31.22)	-587.39 (34.68)	106.76 (22.91)	126.18 (29.94)
28	1	-331.53 (44.48)	-494.05 (28.33)	113.60 (14.72)	140.91 (33.19)
	2	-352.68 (28.81)	-491.81 (19.89)	127.64 (40.31)	176.25 (19.64)
	3	-465.80 (47.81)	-619.63 (49.12)	167.70 (25.30)	214.69 (15.89)
	4	-277.95 (41.05)	-482.92 (17.82)	87.22 (7.37)	104.35 (39.30)
	5	-307.59 (45.03)	-492.54 (14.77)	120.07 (18.02)	163.69 (27.82)
	6	-373.07 (24.51)	-543.33 (21.74)	132.59 (31.72)	184.09 (36.88)
29	1	-275.10 (30.09)	-517.60 (70.05)	218.91 (76.55)	97.18 (21.30)
	2	-300.36 (29.32)	-583.01 (30.18)	262.08 (23.72)	94.08 (20.64)
	3	-364.38 (42.31)	-600.0 (29.66)	264.72 (30.31)	109.78 (51.42)
	4	-334.64 (15.41)	-461.91 (22.46)	225.21 (23.36)	77.16 (45.90)
	5	-339.23 (87.82)	-633.51 (61.24)	361.84 (72.21)	101.10 (65.60)
	6	-343.96 (47.02)	-684.76 (51.51)	357.16 (46.05)	153.37 (72.05)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
31	1	-256.23	-474.65	119.81	158.23
		(75.09)	(43.04)	(65.60)	(47.26)
	2	-362.53	-545.91	127.68	132.09
		(59.90)	(52.43)	(67.07)	(59.80)
	3	-404.04	-621.22	92.05	80.88
		(41.20)	(31.38)	(13.34)	(44.34)
	4	-296.85	-483.31	119.79	115.25
		(33.03)	(45.38)	(33.96)	(25.92)
	5	-442.39	-618.31	122.89	146.01
		(64.44)	(86.31)	(115.21)	(102.81)
	6	-519.68	-680.0	120.71	123.50
		(22.87)	(46.18)	(14.66)	(54.37)
32	1	-203.51	-469.74	158.22	74.65
		(23.63)	(84.46)	(29.56)	(13.05)
	2	-339.76	-561.10	164.69	96.25
		(29.42)	(19.32)	(18.05)	(27.31)
	3	-352.38	-574.50	188.86	34.39
		(16.79)	(33.21)	(19.06)	(8.13)
	4	-327.46	-555.53	163.64	72.54
		(12.97)	(35.16)	(26.56)	(20.41)
	5	-363.59	-614.58	176.32	59.75
		(24.23)	(40.84)	(28.95)	(20.21)
	6	-394.77	-623.42	199.56	38.71
		(36.26)	(60.37)	(21.50)	(13.73)
33	1	-253.22	-418.09	168.09	168.09
		(30.61)	(18.62)	(4.13)	(4.13)
	2	-343.83	-549.82	186.32	186.32
		(41.57)	(41.47)	(16.08)	(16.08)
	3	-382.15	-617.11	199.38	165.16
		-287.35	-510.34	55.52	60.23
	4	-287.35	-510.34	55.52	169.25
		(17.77)	(28.79)	(20.33)	(25.18)
	5	-373.61	-572.65	126.96	184.21
		(46.57)	(19.16)	(22.71)	(34.51)
	6	-362.32	-646.81	227.88	163.0
		(54.44)	(59.32)	(29.85)	(18.63)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
35	1	-329.16 (34.18)	-549.09 (36.91)	210.99 (25.29)	91.43 (21.34)
	2	-332.23 (44.36)	-564.90 (42.74)	277.72 (25.31)	115.17 (31.37)
	3	-352.32 (43.52)	-691.16 (62.56)	344.75 (56.33)	108.87 (40.24)
	4	-320.75 (33.73)	-572.20 (21.15)	252.56 (23.26)	113.02 (18.18)
	5	-334.90 (32.35)	-580.75 (57.85)	285.21 (14.32)	125.94 (29.61)
	6	-269.51 (262.18)	-554.69 (310.04)	256.41 (156.21)	113.76 (27.91)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AE

Male Subject Table Right Hip Angle Data

Male subject right hip angle data.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
2	1	10.73 (2.20)	33.89 (5.33)	23.16 (5.0)	-5.11 (2.16)	0.33 (2.23)	7.18 (1.79)	5.68 (3.82)
	2	13.83 (2.0)	47.79 (6.33)	33.96 (4.54)	-5.79 (1.28)	-0.38 (2.29)	9.08 (3.13)	2.89 (2.32)
	3	20.55 (1.25)	67.82 (9.97)	47.27 (9.56)	-6.50 (2.10)	1.11 (2.52)	8.54 (2.11)	5.18 (2.69)
	4	8.55 (2.67)	27.43 (0.99)	18.88 (2.90)	-3.94 (2.10)	1.67 (0.90)	6.93 (1.38)	1.25 (1.39)
	5	11.25 (1.99)	38.43 (5.81)	27.19 (4.53)	-3.57 (3.02)	0.62 (1.84)	8.25 (2.16)	6.59 (1.36)
	6	19.84 (2.10)	64.82 (9.76)	44.98 (8.97)	-3.06 (2.87)	1.42 (2.05)	8.75 (3.19)	2.36 (2.22)
7	1	15.77 (3.61)	68.67 (11.74)	56.56 (9.96)	-12.09 (3.17)	1.65 (4.28)	6.39 (3.69)	3.60 (6.10)
	2	17.10 (4.69)	77.54 (9.17)	61.28 (8.53)	-14.20 (2.64)	-0.03 (3.09)	7.39 (2.35)	6.50 (3.53)
	3	17.96 (1.85)	102.36 (9.01)	62.58 (46.53)	-11.11 (1.87)	4.23 (3.44)	28.25 (33.52)	14.04 (8.70)
	4	16.11 (3.88)	72.91 (5.17)	58.92 (4.64)	-12.63 (1.03)	1.10 (1.92)	1.70 (1.44)	3.12 (1.85)
	5	12.87 (5.97)	80.24 (5.21)	68.31 (5.17)	-10.65 (2.78)	2.43 (1.02)	4.80 (1.60)	6.05 (4.30)
	6	18.18 (4.84)	90.56 (5.28)	72.51 (3.70)	-11.14 (4.28)	0.99 (6.57)	5.86 (1.97)	4.75 (1.36)
9	1	17.91 (4.38)	68.96 (7.86)	51.05 (4.05)	-5.0 (2.92)	-2.36 (2.70)	3.82 (2.92)	1.84 (3.06)
	2	27.37 (2.89)	80.82 (8.97)	53.45 (6.12)	-5.79 (2.88)	-4.10 (2.55)	-0.58 (4.17)	-2.17 (3.65)
	3	31.06 (2.38)	96.95 (5.26)	65.89 (3.03)	-9.29 (0.94)	-5.69 (2.47)	-0.57 (1.36)	2.73 (1.25)
	4	19.50 (2.80)	58.06 (3.61)	38.56 (2.56)	-2.02 (1.68)	-1.45 (2.30)	4.79 (1.83)	0.62 (0.90)
	5	23.22 (2.81)	70.94 (7.40)	47.72 (4.82)	-5.86 (1.97)	-4.38 (2.24)	1.75 (3.41)	-2.35 (2.82)
	6	27.98 (1.96)	88.21 (8.70)	60.23 (7.82)	-8.12 (2.49)	-3.49 (3.85)	0.40 (4.27)	0.70 (3.02)

Continued.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
11	1	16.74	77.74	60.29	-15.70	-9.89	5.96	5.23
		(3.14)	(5.03)	(5.24)	(3.82)	(3.45)	(4.29)	(5.10)
	2	19.83	90.26	50.28	-10.89	-8.12	59.93	96.01
		(8.60)	(9.59)	(43.56)	(5.42)	(4.55)	(70.53)	(148.28)
	3	25.78	98.12	56.37	-20.01	-9.16	18.28	22.37
		(2.23)	(14.53)	(46.59)	(2.98)	(8.53)	(23.49)	(25.83)
	4	15.71	67.25	51.50	-15.52	-6.20	3.68	4.10
		(2.88)	(5.47)	(3.62)	(3.18)	(3.79)	(2.69)	(2.15)
	5	19.74	88.64	51.12	-17.76	-10.54	9.52	16.46
		(3.14)	(6.98)	(39.46)	(2.93)	(8.09)	(16.79)	(19.30)
	6	22.67	90.72	68.05	-15.43	-8.48	15.19	18.90
		(1.35)	(4.70)	(5.05)	(2.85)	(2.70)	(15.07)	(15.28)
18	1	26.23	59.33	33.10	-3.68	3.34	7.0	0.86
		(2.65)	(3.59)	(1.89)	(3.63)	(2.85)	(1.35)	(3.41)
	2	28.73	82.12	53.39	-4.07	1.04	9.59	1.83
		(1.90)	(3.46)	(3.13)	(1.0)	(1.42)	(2.22)	(2.23)
	3	32.17	89.36	57.20	-3.96	3.13	10.56	4.70
		(3.62)	(4.54)	(2.69)	(2.38)	(1.38)	(1.52)	(3.93)
	4	23.42	62.80	39.38	-2.70	3.49	11.79	3.75
		(1.71)	(6.83)	(7.76)	(3.11)	(2.04)	(3.15)	(2.63)
	5	22.58	66.02	43.44	-3.90	4.65	10.52	4.66
		(1.79)	(4.46)	(3.15)	(2.41)	(0.79)	(1.02)	(2.90)
	6	27.32	77.88	50.56	-4.93	3.01	8.29	3.52
		(2.95)	(4.76)	(2.99)	(2.13)	(1.68)	(2.25)	(2.95)
22	1	25.36	78.51	53.14	-10.88	-3.20	18.41	5.20
		(3.42)	(2.52)	(5.43)	(1.87)	(1.87)	(4.52)	(4.83)
	2	33.44	99.15	65.70	-13.98	-6.07	16.38	13.28
		(1.41)	(2.84)	(1.95)	(2.17)	(1.87)	(5.74)	(6.98)
	3	34.42	104.64	70.22	-13.08	-5.63	10.76	8.20
		(2.04)	(2.41)	(2.78)	(2.50)	(1.83)	(2.55)	(4.83)
	4	30.22	93.11	62.88	-11.45	-4.40	20.11	12.07
		(3.59)	(1.50)	(4.61)	(1.51)	(0.76)	(3.90)	(4.59)
	5	33.02	103.65	70.63	-13.24	-5.01	14.43	9.06
		(2.89)	(3.55)	(2.41)	(1.92)	(1.26)	(1.12)	(1.54)
	6	34.18	107.02	72.84	-13.92	-5.11	12.35	7.67
		(2.72)	(3.12)	(1.88)	(2.26)	(1.44)	(3.18)	(3.28)

Continued.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
24	1	14.09	35.83	22.61	-8.51	-1.66	5.73	4.93
		(1.86)	(5.07)	(5.80)	(0.94)	(1.27)	(2.03)	(2.67)
	2	24.30	84.49	60.15	-6.75	1.17	9.36	3.80
		(2.16)	(5.23)	(3.94)	(2.26)	(3.78)	(0.95)	(2.85)
	3	27.98	113.39	85.89	-11.62	-4.64	9.31	5.07
		(1.87)	(2.74)	(2.62)	(1.18)	(2.42)	(1.40)	(1.77)
	4	13.40	38.42	24.96	-9.78	-1.57	2.62	3.57
		(1.18)	(9.09)	(9.22)	(0.71)	(0.43)	(1.69)	(2.17)
	5	11.20	35.33	24.13	-10.15	-3.34	5.09	5.68
		(6.38)	(3.76)	(7.67)	(0.69)	(3.30)	(1.60)	(1.64)
	6	20.98	76.59	55.70	-9.76	-1.65	6.27	3.89
		(1.58)	(7.55)	(7.78)	(0.91)	(1.04)	(1.58)	(1.17)
25	1	22.79	53.94	31.15	-11.26	2.38	2.96	7.0
		(2.94)	(4.73)	(2.49)	(1.73)	(1.75)	(1.0)	(1.17)
	2	29.78	75.99	46.21	-12.72	-0.75	4.80	6.56
		(4.0)	(4.15)	(2.58)	(2.28)	(2.54)	(2.15)	(1.06)
	3	29.51	98.10	68.60	-17.39	-6.48	4.53	4.11
		(1.63)	(3.0)	(4.21)	(1.60)	(0.73)	(1.97)	(2.80)
	4	24.20	51.40	27.21	-9.33	1.85	4.53	6.39
		(5.52)	(5.24)	(3.89)	(2.67)	(2.64)	(0.74)	(1.88)
	5	27.17	80.11	52.95	-14.03	-1.89	5.30	7.04
		(3.21)	(4.47)	(4.14)	(1.31)	(2.53)	(1.62)	(2.12)
	6	30.64	101.87	71.23	-16.13	-5.16	7.80	6.80
		(3.36)	(2.19)	(4.48)	(2.36)	(2.25)	(3.65)	(4.59)
26	1	4.56	23.16	18.60	-4.36	-2.39	13.47	4.59
		(0.73)	(2.92)	(3.02)	(1.50)	(2.06)	(0.50)	(1.72)
	2	16.68	40.68	24.0	-10.99	-0.67	10.91	3.80
		(2.08)	(4.73)	(2.90)	(2.49)	(4.16)	(5.0)	(2.32)
	3	21.09	54.17	33.08	-7.55	-0.05	3.21	3.80
		(2.04)	(4.33)	(3.10)	(2.40)	(1.08)	(2.39)	(2.73)
	4	18.60	44.26	25.66	-8.67	-2.26	2.43	3.36
		(1.80)	(5.72)	(4.92)	(2.19)	(1.28)	(1.77)	(1.05)
	5	14.59	45.16	30.56	-6.83	-0.32	13.0	4.68
		(1.65)	(8.16)	(7.96)	(1.17)	(2.91)	(4.91)	(4.10)
	6	21.42	53.0	31.58	-8.34	-0.22	5.65	3.61
		(1.54)	(4.23)	(3.07)	(2.07)	(0.47)	(2.84)	(2.44)

Continued.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
27	1	24.23	62.90	38.67	-20.82	-3.25	0.38	6.62
		(1.96)	(3.58)	(2.03)	(1.24)	(4.18)	(1.48)	(3.57)
	2	23.24	62.21	38.98	-21.58	-11.90	-0.92	1.80
		(3.07)	(3.41)	(4.50)	(2.15)	(3.22)	(1.10)	(2.05)
	3	28.33	85.31	56.98	-20.75	-4.08	7.25	11.10
		(1.77)	(4.40)	(4.07)	(1.53)	(1.08)	(4.61)	(4.30)
	4	17.97	38.78	20.69	-10.37	-5.32	2.55	0.53
		(4.37)	(2.58)	(4.05)	(2.66)	(5.33)	(1.70)	(7.42)
	5	24.15	61.57	37.42	-17.27	-7.01	-1.65	2.90
		(4.74)	(2.80)	(4.47)	(1.96)	(3.05)	(1.89)	(1.17)
	6	24.83	68.26	43.43	-19.06	-4.86	1.04	5.56
		(3.70)	(5.49)	(7.03)	(1.30)	(4.41)	(2.50)	(3.92)
28	1	24.54	68.20	43.66	-14.96	4.21	5.08	3.59
		(1.77)	(8.29)	(7.84)	(2.16)	(1.72)	(2.95)	(2.21)
	2	31.29	74.45	43.75	-18.16	4.57	2.54	1.77
		(2.52)	(3.35)	(3.03)	(1.37)	(2.35)	(1.91)	(1.15)
	3	35.08	103.05	67.96	-13.93	4.05	5.57	13.23
		(1.59)	(11.35)	(11.77)	(3.12)	(1.79)	(4.34)	(5.89)
	4	21.60	56.71	35.11	-18.89	0.02	1.95	3.60
		(2.46)	(4.83)	(3.06)	(2.66)	(3.18)	(1.94)	(2.30)
	5	28.47	73.25	44.78	-16.66	4.65	4.26	1.04
		(1.96)	(1.32)	(2.55)	(1.62)	(2.67)	(1.66)	(1.27)
	6	31.43	84.18	52.74	-15.24	3.89	6.82	5.97
		(1.29)	(9.91)	(8.74)	(3.33)	(0.97)	(2.76)	(3.42)
29	1	17.13	63.37	46.18	-18.67	-5.34	5.52	9.97
		(5.44)	(14.58)	(15.83)	(2.74)	(1.10)	(1.45)	(4.83)
	2	17.91	54.33	36.43	-18.61	-7.69	3.48	11.06
		(4.53)	(3.87)	(2.13)	(0.85)	(2.43)	(1.75)	(1.86)
	3	21.77	80.34	58.57	-25.95	-9.58	5.92	14.99
		(2.33)	(6.70)	(8.0)	(2.15)	(2.24)	(1.18)	(1.27)
	4	15.50	43.65	28.15	-23.04	-7.83	-0.43	8.95
		(3.77)	(7.07)	(5.96)	(2.65)	(1.66)	(1.73)	(3.38)
	5	17.83	70.60	52.76	-25.98	-8.17	5.76	14.22
		(1.68)	(6.83)	(7.36)	(1.73)	(1.28)	(1.09)	(1.40)
	6	19.83	83.47	63.64	-27.39	-8.06	7.60	17.82
		(1.74)	(6.84)	(5.51)	(2.35)	(2.80)	(1.16)	(2.07)

Continued.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
31	1	30.19	50.45	20.26	-2.31	2.20	23.95	-2.06
		(1.92)	(8.34)	(6.62)	(2.47)	(2.70)	(4.88)	(1.72)
	2	36.11	61.48	25.37	4.27	5.0	29.53	-3.21
		(3.48)	(8.33)	(5.34)	(1.39)	(4.15)	(2.63)	(2.42)
	3	40.06	76.76	36.70	4.35	7.53	25.50	-3.02
		(2.61)	(3.0)	(4.32)	(1.41)	(3.36)	(2.95)	(2.77)
	4	35.40	62.47	27.08	9.43	5.87	28.73	-3.44
		(3.31)	(7.87)	(5.55)	(2.65)	(2.50)	(3.12)	(1.83)
	5	40.59	69.88	29.29	8.97	8.19	28.77	-3.21
		(3.69)	(4.19)	(4.04)	(4.25)	(6.13)	(2.89)	(3.67)
	6	43.54	96.82	53.28	-1.28	6.52	20.65	-4.82
		(1.24)	(2.42)	(1.54)	(3.08)	(2.24)	(0.73)	(2.95)
32	1	8.30	37.83	29.52	-11.12	-7.56	6.99	7.21
		(3.80)	(16.61)	(12.94)	(1.63)	(3.36)	(2.34)	(4.50)
	2	12.50	65.56	53.06	-16.60	-10.15	12.26	11.13
		(1.28)	(3.31)	(3.57)	(1.84)	(3.23)	(1.51)	(2.80)
	3	15.41	79.40	64.0	-21.80	-15.95	8.81	14.35
		(1.72)	(4.50)	(3.59)	(1.58)	(1.10)	(0.89)	(1.92)
	4	11.14	62.80	51.66	-14.72	-10.93	12.43	10.51
		(2.08)	(7.52)	(7.86)	(1.66)	(1.67)	(1.63)	(1.66)
	5	14.60	84.99	70.38	-22.56	-15.53	12.54	14.73
		(1.76)	(3.80)	(4.49)	(1.18)	(2.34)	(1.29)	(1.32)
	6	13.97	87.85	73.88	-23.11	-16.87	10.04	13.84
		(2.24)	(2.76)	(3.50)	(1.53)	(3.48)	(2.43)	(3.41)
33	1	14.27	25.79	11.53	-7.04	-3.61	-1.22	2.21
		(1.27)	(1.38)	(0.34)	(1.35)	(0.35)	(1.57)	(1.32)
	2	16.55	44.66	28.10	-10.55	-3.30	-5.57	0.19
		(1.81)	(3.83)	(2.40)	(0.75)	(1.64)	(1.44)	(2.29)
	3	17.68	56.98	39.31	-18.54	-6.54	-3.26	4.0
		16.79	44.02	27.23	-13.49	-1.45	0.84	0.82
	4	16.79	44.02	27.23	-13.49	-1.45	-5.47	0.24
		(1.28)	(1.92)	(1.38)	(1.66)	(0.34)	(0.82)	(1.23)
	5	18.12	47.19	29.07	-14.81	-2.37	-4.48	0.86
		(1.33)	(3.54)	(3.86)	(2.62)	(1.47)	(1.04)	(2.82)
	6	19.19	48.97	29.78	-17.40	-5.71	-3.42	-1.91
		(0.85)	(0.97)	(0.81)	(1.93)	(1.50)	(1.73)	(2.55)

Continued.

Subject	Condition	Contact	Flexion	Flexion ROM	Abd	Abd ROM	Internal Rotat	Int Rotat ROM
35	1	15.67	86.19	70.51	-28.27	-17.70	-0.14	5.14
		(2.90)	(5.15)	(3.87)	(2.58)	(2.73)	(3.67)	(3.88)
	2	25.23	98.23	73.0	-34.23	-17.57	9.52	18.85
		(2.05)	(3.34)	(4.16)	(1.99)	(2.73)	(3.04)	(2.84)
	3	27.37	106.56	79.19	-32.97	-17.11	17.18	26.13
		(1.61)	(3.59)	(3.67)	(2.17)	(1.79)	(3.55)	(3.69)
	4	20.17	94.40	74.23	-30.23	-16.16	7.18	13.87
		(2.11)	(1.67)	(2.81)	(2.88)	(1.33)	(1.48)	(2.33)
	5	26.66	102.10	77.37	-34.84	-18.68	14.79	21.99
		(1.81)	(6.26)	(6.67)	(1.67)	(2.68)	(6.42)	(5.51)
	6	35.04	107.54	55.86	-24.78	-9.46	15.42	22.58
		(7.93)	(2.39)	(45.01)	(7.68)	(6.20)	(10.13)	(14.64)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AF

Male Subject Table Right Hip Angular Velocity Data

Male subject hip angular velocity data.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
2	1	114.56	320.17	-75.15	188.66
		(27.91)	(62.40)	(7.99)	(35.59)
	2	163.71	368.09	-83.25	202.13
		(35.32)	(48.11)	(15.04)	(34.95)
	3	208.12	528.39	-90.31	180.72
		(31.28)	(41.49)	(49.68)	(38.80)
	4	117.72	239.45	-69.52	179.64
		(56.53)	(23.44)	(29.45)	(33.48)
	5	153.35	353.33	-75.29	205.95
		(43.18)	(69.31)	(19.70)	(47.09)
	6	211.09	478.80	-80.41	184.78
		(51.11)	(59.46)	(34.28)	(46.29)
7	1	152.07	468.35	-97.97	109.69
		(25.34)	(30.27)	(21.42)	(25.12)
	2	138.91	499.05	-125.46	138.74
		(24.03)	(53.91)	(36.91)	(13.64)
	3	202.35	558.15	-184.13	194.19
		(20.92)	(44.16)	(45.18)	(30.79)
	4	146.55	409.38	-84.63	118.84
		(38.33)	(43.54)	(20.83)	(33.60)
	5	171.70	482.79	-94.86	177.72
		(26.92)	(20.70)	(24.53)	(45.29)
	6	193.21	553.68	-107.76	150.33
		(16.47)	(27.38)	(36.76)	(25.60)
9	1	193.20	425.42	-94.46	175.44
		(39.61)	(38.50)	(27.53)	(65.91)
	2	225.32	479.70	-79.65	133.32
		(52.86)	(34.34)	(28.28)	(70.18)
	3	263.78	567.19	-126.02	157.40
		(25.52)	(18.59)	(42.43)	(46.75)
	4	164.74	354.39	-83.35	178.78
		(23.67)	(38.80)	(15.41)	(15.06)
	5	194.62	419.82	-85.15	143.87
		(17.71)	(30.72)	(24.60)	(61.22)
	6	236.0	478.65	-120.07	138.52
		(26.57)	(48.70)	(60.36)	(47.89)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
11	1	123.83 (31.75)	414.49 (41.79)	-87.13 (44.19)	204.26 (58.86)
	2	144.91 (42.56)	455.02 (124.42)	-345.46 (484.30)	257.89 (143.01)
	3	167.52 (47.50)	539.84 (25.27)	-150.41 (52.16)	122.34 (42.18)
	4	112.99 (9.78)	368.70 (35.17)	-107.96 (36.48)	178.97 (37.29)
	5	139.93 (49.67)	489.11 (41.77)	-130.72 (67.86)	165.12 (15.22)
	6	162.35 (13.33)	526.39 (42.45)	-145.66 (112.53)	175.44 (27.84)
18	1	128.05 (8.08)	368.02 (76.26)	-73.97 (23.32)	158.58 (37.51)
	2	208.73 (29.63)	533.81 (31.19)	-144.04 (35.47)	191.08 (42.91)
	3	217.26 (18.66)	552.03 (72.49)	-166.38 (68.19)	185.58 (80.50)
	4	146.29 (19.23)	363.28 (74.41)	-104.11 (37.10)	174.47 (59.96)
	5	145.01 (38.99)	454.11 (43.43)	-102.87 (35.96)	189.68 (28.46)
	6	172.36 (31.09)	513.03 (63.12)	-112.46 (23.54)	154.70 (34.0)
22	1	283.66 (63.78)	404.75 (54.77)	-233.97 (99.47)	187.29 (75.42)
	2	324.81 (14.68)	416.63 (35.76)	-262.33 (143.82)	198.12 (92.74)
	3	376.25 (66.08)	481.13 (37.25)	-205.62 (79.02)	160.55 (66.67)
	4	304.57 (35.83)	464.31 (58.04)	-231.78 (78.13)	225.83 (100.19)
	5	330.71 (30.15)	513.40 (69.02)	-182.23 (87.39)	160.50 (57.48)
	6	350.53 (51.92)	479.14 (38.50)	-198.77 (82.88)	157.41 (73.62)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
24	1	78.08 (6.42)	195.04 (23.94)	-63.33 (14.53)	143.36 (43.89)
	2	91.87 (26.71)	402.21 (14.61)	-198.50 (18.48)	230.17 (21.28)
	3	130.40 (18.53)	585.91 (32.99)	-199.66 (15.13)	205.30 (43.91)
	4	59.37 (10.32)	189.28 (17.05)	-45.31 (15.51)	147.77 (23.34)
	5	65.79 (38.02)	231.83 (16.92)	-80.40 (17.24)	179.85 (20.85)
	6	82.68 (16.37)	379.60 (36.68)	-142.28 (24.85)	175.57 (29.21)
25	1	165.14 (16.66)	285.35 (52.08)	-81.57 (29.66)	143.96 (50.94)
	2	176.27 (13.86)	418.82 (14.86)	-114.98 (43.85)	169.56 (41.33)
	3	199.74 (28.38)	528.48 (33.49)	-110.46 (37.45)	161.32 (26.78)
	4	158.07 (21.63)	289.27 (33.19)	-83.87 (11.68)	180.83 (36.41)
	5	189.47 (16.01)	395.79 (34.79)	-108.32 (32.64)	119.61 (62.82)
	6	200.63 (27.34)	546.12 (29.11)	-69.55 (23.50)	216.90 (48.29)
26	1	63.28 (24.88)	292.24 (24.54)	-120.83 (18.75)	146.19 (32.0)
	2	87.27 (6.67)	333.19 (66.07)	-194.79 (125.64)	196.46 (69.15)
	3	100.02 (22.15)	464.39 (63.32)	-147.50 (24.33)	194.0 (49.23)
	4	53.24 (33.24)	364.62 (59.32)	-124.76 (29.21)	216.59 (20.51)
	5	101.33 (17.53)	328.23 (202.25)	-180.36 (73.15)	217.96 (45.82)
	6	116.68 (42.21)	442.66 (67.02)	-147.53 (18.30)	179.59 (12.72)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
27	1	155.38 (27.84)	385.32 (46.58)	-83.62 (28.33)	63.77 (14.49)
	2	136.31 (35.57)	428.83 (34.26)	-110.54 (47.77)	116.30 (28.51)
	3	192.29 (32.97)	509.88 (56.46)	-105.20 (60.18)	124.44 (8.51)
	4	66.40 (58.31)	321.62 (37.73)	-86.33 (76.02)	101.76 (47.66)
	5	140.27 (37.35)	424.30 (28.05)	-61.92 (16.33)	89.93 (19.42)
	6	147.48 (16.86)	433.90 (66.64)	-69.72 (22.14)	102.83 (29.56)
28	1	156.39 (24.52)	346.77 (56.73)	-102.60 (53.82)	115.13 (48.61)
	2	141.50 (20.77)	392.27 (58.26)	-129.43 (37.06)	132.48 (21.57)
	3	196.97 (27.51)	490.50 (33.80)	-157.09 (26.97)	162.95 (41.34)
	4	104.09 (31.03)	283.27 (56.44)	-72.54 (30.10)	137.98 (27.85)
	5	137.37 (21.54)	379.50 (43.41)	-116.44 (26.37)	115.39 (13.79)
	6	164.81 (26.28)	409.35 (53.38)	-130.68 (39.48)	163.56 (61.75)
29	1	168.20 (17.47)	365.53 (79.22)	-93.58 (35.80)	151.92 (53.60)
	2	150.59 (21.26)	367.73 (28.74)	-122.38 (18.12)	200.07 (18.58)
	3	172.0 (40.52)	415.38 (16.69)	-134.68 (31.45)	183.34 (17.85)
	4	138.40 (14.92)	282.93 (26.23)	-106.90 (19.77)	126.50 (50.95)
	5	156.72 (23.66)	413.25 (29.70)	-167.32 (18.34)	202.68 (34.65)
	6	184.19 (22.28)	430.02 (64.95)	-199.60 (27.37)	198.75 (41.37)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
31	1	127.38	207.93	-32.04	66.59
		(43.90)	(46.51)	(11.37)	(27.97)
	2	140.90	283.55	-32.30	77.02
		(51.14)	(60.74)	(11.95)	(48.04)
	3	205.10	359.97	-37.97	75.10
		(19.17)	(19.26)	(24.17)	(15.79)
	4	141.56	287.75	-60.92	86.32
		(44.08)	(25.08)	(47.66)	(44.69)
	5	202.43	304.80	-38.33	124.60
		(30.91)	(22.53)	(5.37)	(46.51)
	6	292.47	451.26	-47.27	59.11
		(22.55)	(40.42)	(6.51)	(10.62)
32	1	81.88	275.40	-83.98	129.50
		(13.96)	(86.16)	(7.14)	(27.81)
	2	160.22	376.43	-98.23	114.37
		(21.77)	(17.20)	(29.95)	(21.93)
	3	154.33	419.61	-91.44	116.25
		(18.19)	(25.55)	(18.22)	(3.02)
	4	153.73	348.88	-104.82	113.03
		(21.58)	(34.60)	(20.29)	(35.32)
	5	174.92	454.38	-107.0	104.30
		(26.80)	(25.05)	(15.44)	(27.84)
	6	186.98	459.38	-95.01	101.27
		(10.11)	(29.87)	(25.03)	(24.30)
33	1	35.47	150.22	-120.20	89.40
		(17.81)	(17.07)	(37.59)	(24.72)
	2	95.66	258.17	-114.41	65.21
		(19.05)	(23.56)	(44.0)	(16.29)
	3	115.83	344.79	-109.61	88.94
		82.17	227.45	-35.60	26.80
	4	82.17	227.45	-35.60	51.54
		(6.76)	(30.48)	(14.85)	(8.87)
	5	124.32	272.25	-79.25	76.94
		(23.52)	(24.39)	(14.77)	(20.66)
	6	118.78	330.36	-131.24	118.51
		(21.88)	(14.32)	(26.27)	(40.16)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
35	1	144.88	411.92	-106.25	44.75
		(33.29)	(28.35)	(23.15)	(16.17)
	2	151.79	407.35	-163.57	47.76
		(13.42)	(42.21)	(23.59)	(20.54)
	3	155.09	507.05	-208.66	61.47
		(26.63)	(8.79)	(13.69)	(11.05)
	4	156.41	397.19	-117.36	30.84
		(17.76)	(7.94)	(18.57)	(13.12)
	5	167.72	406.35	-170.53	47.31
		(15.31)	(19.92)	(27.44)	(23.68)
	6	114.70	417.91	-204.66	94.60
		(137.24)	(237.65)	(105.78)	(45.13)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AG

Male Subject Table GRF Data

Male subject GRF force data.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
2	1	-0.65	0.01	3.32	0.01	7.55	0.05	462.14	158.88	1.07
		(0.03)	(0.0)	(0.08)	(0.0)	(1.10)	(0.0)	(125.39)	(23.29)	(0.04)
	2	-0.91	0.01	2.98	0.01	5.23	0.05	303.46	110.48	0.73
		(0.07)	(0.0)	(0.14)	(0.0)	(0.59)	(0.0)	(43.95)	(14.96)	(0.05)
	3	-1.22	0.01	3.06	0.01	5.43	0.04	401.31	174.67	0.60
		(0.20)	(0.0)	(0.27)	(0.0)	(1.48)	(0.01)	(210.26)	(96.27)	(0.05)
	4	-0.65	0.01	3.51	0.01	8.47	0.06	342.69	146.23	1.17
		(0.02)	(0.0)	(0.15)	(0.0)	(0.57)	(0.0)	(133.75)	(13.36)	(0.03)
	5	-0.82	0.01	3.15	0.01	6.20	0.05	493.51	138.41	0.86
		(0.07)	(0.0)	(0.17)	(0.0)	(0.54)	(0.0)	(242.76)	(29.10)	(0.07)
	6	-1.0	0.01	2.89	0.01	5.34	0.04	596.15	142.83	0.68
		(0.11)	(0.0)	(0.12)	(0.0)	(0.77)	(0.0)	(231.24)	(33.95)	(0.04)
7	1	-0.41	0.01	1.86	0.01	7.07	0.04	424.55	199.54	1.07
		(0.07)	(0.0)	(0.28)	(0.0)	(1.53)	(0.0)	(290.67)	(46.70)	(0.09)
	2	-0.62	0.01	1.96	0.01	5.44	0.05	275.04	156.73	0.72
		(0.11)	(0.0)	(0.44)	(0.0)	(0.73)	(0.01)	(165.55)	(39.91)	(0.06)
	3	-1.0	0.01	2.81	0.01	4.70	0.05	249.72	141.08	0.56
		(0.10)	(0.0)	(0.36)	(0.0)	(0.56)	(0.0)	(19.78)	(34.06)	(0.03)
	4	-0.29	0.04	1.60	0.01	6.33	0.06	177.28	132.56	1.20
		(0.03)	(0.04)	(0.18)	(0.0)	(1.03)	(0.01)	(38.67)	(40.77)	(0.03)
	5	-0.49	0.01	2.22	0.01	5.50	0.06	174.75	123.30	0.87
		(0.04)	(0.0)	(0.32)	(0.0)	(0.43)	(0.01)	(30.42)	(37.27)	(0.03)
	6	-0.75	0.01	2.08	0.01	5.85	0.04	470.66	187.78	0.69
		(0.06)	(0.0)	(0.09)	(0.0)	(0.62)	(0.0)	(221.79)	(36.30)	(0.06)
9	1	-0.66	0.01	2.83	0.01	6.09	0.06	374.05	127.76	1.02
		(0.03)	(0.0)	(0.14)	(0.0)	(0.91)	(0.01)	(206.79)	(48.85)	(0.03)
	2	-1.04	0.01	3.50	0.01	5.38	0.05	463.41	131.37	0.78
		(0.08)	(0.0)	(0.25)	(0.0)	(0.90)	(0.0)	(194.03)	(47.73)	(0.04)
	3	-1.34	0.01	3.32	0.01	5.0	0.04	445.34	155.69	0.64
		(0.09)	(0.0)	(0.14)	(0.0)	(0.78)	(0.0)	(98.75)	(47.0)	(0.06)
	4	-0.61	0.01	3.37	0.01	5.80	0.06	314.47	93.77	1.11
		(0.05)	(0.0)	(0.10)	(0.0)	(0.41)	(0.01)	(70.58)	(29.48)	(0.02)
	5	-0.84	0.01	3.25	0.01	4.81	0.05	332.32	93.33	0.85
		(0.09)	(0.0)	(0.20)	(0.0)	(0.62)	(0.01)	(109.11)	(28.62)	(0.01)
	6	-1.24	0.01	3.59	0.010	4.63	0.048	396.03	105.65	0.70
		(0.10)	(0.0)	(0.20)	0.003	(0.72)	0.006	(122.42)	(27.44)	(0.03)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
11	1	-0.61	0.02	2.75	0.03	6.45	0.05	274.21	178.23	0.95
		(0.16)	(0.03)	(0.22)	(0.05)	(2.20)	(0.01)	(180.53)	(108.21)	(0.07)
	2	-1.02	0.01	2.68	0.01	5.07	0.04	436.97	157.93	0.66
		(0.04)	(0.0)	(0.25)	(0.0)	(0.59)	(0.0)	(180.42)	(35.25)	(0.06)
	3	-1.17	0.01	2.90	0.01	4.14	0.04	531.14	125.23	0.54
		(0.10)	(0.0)	(0.17)	(0.0)	(1.07)	(0.0)	(164.73)	(59.93)	(0.04)
	4	-0.58	0.01	2.59	0.01	6.84	0.05	368.55	170.59	1.04
		(0.08)	(0.0)	(0.23)	(0.0)	(0.65)	(0.0)	(88.14)	(32.81)	(0.06)
	5	-0.88	0.0	2.88	0.0	5.35	0.05	805.75	150.37	0.81
		(0.16)	(0.0)	(0.12)	(0.0)	(1.49)	(0.01)	(264.32)	(76.73)	(0.05)
	6	-1.19	0.01	2.85	0.01	5.45	0.04	517.89	189.92	0.61
		(0.04)	(0.0)	(0.17)	(0.0)	(1.23)	(0.0)	(154.45)	(72.65)	(0.07)
18	1	-0.49	0.01	2.27	0.01	5.43	0.04	360.66	130.08	0.92
		(0.03)	(0.0)	(0.08)	(0.0)	(1.25)	(0.01)	(79.88)	(67.92)	(0.03)
	2	-1.13	0.01	3.24	0.01	5.51	0.04	583.84	166.79	0.74
		(0.05)	(0.0)	(0.12)	(0.0)	(0.83)	(0.0)	(112.34)	(48.19)	(0.03)
	3	-1.42	0.01	3.17	0.01	5.21	0.04	592.49	191.54	0.60
		(0.06)	(0.0)	(0.09)	(0.0)	(1.48)	(0.01)	(327.92)	(112.86)	(0.03)
	4	-0.47	0.02	2.80	0.01	6.27	0.05	597.27	136.84	1.32
		(0.14)	(0.02)	(0.46)	(0.0)	(0.79)	(0.01)	(319.86)	(67.79)	(0.07)
	5	-0.64	0.01	2.64	0.01	5.78	0.04	529.16	136.70	0.98
		(0.05)	(0.0)	(0.14)	(0.0)	(0.69)	(0.0)	(297.25)	(37.08)	(0.02)
	6	-1.01	0.01	3.06	0.01	5.44	0.04	548.43	146.72	0.75
		(0.15)	(0.0)	(0.28)	(0.0)	(0.53)	(0.0)	(353.93)	(32.35)	(0.02)
22	1	-0.42	0.01	2.11	0.01	4.02	0.06	297.68	50.22	1.04
		(0.16)	(0.01)	(0.11)	(0.0)	(0.25)	(0.02)	(104.38)	(16.20)	(0.05)
	2	-0.81	0.01	2.24	0.01	3.60	0.06	333.40	55.86	0.73
		(0.06)	(0.0)	(0.14)	(0.0)	(0.30)	(0.01)	(147.13)	(10.0)	(0.02)
	3	-0.93	0.0	2.06	0.0	2.97	0.05	539.51	47.36	0.56
		(0.09)	(0.0)	(0.12)	(0.0)	(0.60)	(0.01)	(200.85)	(30.24)	(0.0)
	4	-0.64	0.01	2.14	0.01	4.35	0.06	297.33	87.67	0.87
		(0.08)	(0.0)	(0.16)	(0.0)	(0.94)	(0.01)	(191.96)	(78.05)	(0.05)
	5	-0.95	0.01	2.22	0.01	3.81	0.05	306.96	80.42	0.64
		(0.08)	(0.0)	(0.12)	(0.0)	(0.60)	(0.01)	(104.19)	(33.66)	(0.03)
	6	-0.97	0.01	1.97	0.01	2.90	0.05	282.79	50.39	0.52
		(0.12)	(0.0)	(0.16)	(0.0)	(0.44)	(0.01)	(107.91)	(22.37)	(0.04)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
24	1	-0.35	0.02	2.69	0.02	5.27	0.08	161.04	65.15	1.05
		(0.03)	(0.0)	(0.18)	(0.0)	(0.79)	(0.0)	(28.37)	(14.43)	(0.06)
	2	-0.77	0.01	2.32	0.01	5.93	0.05	258.79	171.56	0.79
		(0.11)	(0.0)	(0.22)	(0.0)	(0.59)	(0.0)	(86.45)	(37.45)	(0.04)
	3	-0.98	0.01	2.99	0.01	5.05	0.04	359.09	167.95	0.60
		(0.14)	(0.0)	(0.17)	(0.0)	(0.64)	(0.0)	(59.98)	(40.24)	(0.03)
	4	-0.29	0.01	2.41	0.02	6.89	0.08	150.17	90.77	1.37
		(0.04)	(0.0)	(0.19)	(0.0)	(0.52)	(0.01)	(21.60)	(15.28)	(0.09)
	5	-0.38	0.01	2.50	0.01	5.75	0.07	174.48	86.69	0.99
		(0.04)	(0.0)	(0.04)	(0.0)	(0.34)	(0.0)	(20.46)	(8.39)	(0.04)
	6	-0.42	0.01	2.19	0.01	4.99	0.06	170.08	96.18	0.82
		(0.03)	(0.0)	(0.06)	(0.0)	(0.24)	(0.01)	(45.22)	(10.16)	(0.05)
25	1	-0.45	0.01	3.11	0.01	5.55	0.07	254.40	94.23	1.01
		(0.06)	(0.0)	(0.21)	(0.0)	(0.98)	(0.01)	(82.01)	(33.84)	(0.04)
	2	-0.66	0.01	2.75	0.01	4.16	0.05	284.61	90.29	0.75
		(0.04)	(0.0)	(0.22)	(0.0)	(0.68)	(0.01)	(99.46)	(23.90)	(0.07)
	3	-0.80	0.01	2.99	0.01	3.23	0.05	259.70	72.82	0.63
		(0.07)	(0.0)	(0.23)	(0.0)	(0.28)	(0.0)	(57.64)	(16.75)	(0.03)
	4	-0.53	0.01	3.03	0.01	5.80	0.06	384.89	110.49	0.93
		(0.06)	(0.0)	(0.19)	(0.0)	(0.63)	(0.01)	(228.75)	(30.69)	(0.15)
	5	-0.67	0.01	2.69	0.01	3.35	0.06	258.87	56.29	0.73
		(0.04)	(0.0)	(0.15)	(0.0)	(0.44)	(0.01)	(82.63)	(18.32)	(0.05)
	6	-0.75	0.01	3.15	0.01	3.09	0.06	333.71	63.30	0.59
		(0.13)	(0.0)	(0.31)	(0.0)	(0.43)	(0.01)	(97.17)	(18.67)	(0.04)
26	1	-0.53	0.01	3.04	0.01	6.94	0.06	303.30	130.78	1.05
		(0.02)	(0.0)	(0.16)	(0.0)	(1.01)	(0.0)	(74.17)	(33.93)	(0.04)
	2	-0.80	0.01	3.21	0.01	5.67	0.05	391.42	134.93	0.72
		(0.08)	(0.0)	(0.21)	(0.0)	(0.67)	(0.0)	(167.14)	(32.82)	(0.03)
	3	-1.13	0.01	3.32	0.01	5.78	0.04	498.89	195.0	0.54
		(0.02)	(0.0)	(0.23)	(0.0)	(1.20)	(0.0)	(167.03)	(81.21)	(0.04)
	4	-0.57	0.02	2.81	0.01	7.55	0.05	364.29	199.47	0.89
		(0.11)	(0.03)	(0.17)	(0.0)	(0.82)	(0.0)	(123.14)	(45.78)	(0.04)
	5	-0.85	0.01	3.29	0.01	5.74	0.05	419.63	143.94	0.69
		(0.07)	(0.0)	(0.18)	(0.0)	(0.66)	(0.0)	(154.71)	(30.88)	(0.05)
	6	-1.22	0.01	3.44	0.01	5.13	0.04	465.35	157.64	0.53
		(0.08)	(0.0)	(0.29)	(0.0)	(0.47)	(0.0)	(132.37)	(32.87)	(0.01)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
27	1	-0.68 (0.07)	0.01 (0.0)	3.58 (0.29)	0.01 (0.0)	6.77 (1.01)	0.06 (0.01)	664.96 (252.66)	141.05 (54.70)	1.21 (0.05)
	2	-0.96 (0.18)	0.01 (0.0)	3.26 (0.29)	0.01 (0.0)	5.20 (1.18)	0.05 (0.01)	518.84 (90.69)	148.69 (76.08)	0.80 (0.05)
	3	-1.22 (0.10)	0.01 (0.0)	3.65 (0.20)	0.01 (0.0)	3.91 (0.55)	0.05 (0.0)	679.73 (288.61)	91.65 (26.88)	0.66 (0.05)
	4	-0.33 (0.06)	0.01 (0.0)	2.58 (0.37)	0.02 (0.0)	10.30 (0.99)	0.06 (0.01)	159.54 (33.26)	243.21 (80.94)	1.43 (0.09)
	5	-0.56 (0.10)	0.01 (0.0)	2.82 (0.32)	0.01 (0.0)	7.76 (0.60)	0.04 (0.01)	657.70 (519.22)	212.59 (58.16)	1.26 (0.10)
	6	-0.90 (0.07)	0.0 (0.0)	3.41 (0.18)	0.0 (0.0)	5.99 (0.89)	0.04 (0.0)	710.16 (270.86)	165.92 (68.42)	0.95 (0.06)
28	1	-0.43 (0.12)	0.01 (0.0)	2.18 (1.05)	0.02 (0.01)	4.10 (2.25)	0.07 (0.01)	236.13 (128.80)	61.96 (23.46)	0.83 (0.51)
	2	-0.60 (0.16)	0.01 (0.0)	2.55 (0.34)	0.01 (0.0)	4.59 (0.63)	0.06 (0.0)	177.65 (30.37)	79.85 (29.0)	0.73 (0.03)
	3	-0.92 (0.06)	0.01 (0.0)	2.63 (0.33)	0.01 (0.0)	3.93 (0.47)	0.05 (0.01)	315.90 (141.54)	93.47 (13.24)	0.54 (0.02)
	4	-0.38 (0.06)	0.01 (0.0)	2.95 (0.20)	0.01 (0.0)	5.0 (1.23)	0.07 (0.01)	244.09 (84.93)	69.33 (23.93)	1.16 (0.06)
	5	-0.59 (0.03)	0.01 (0.0)	2.54 (0.07)	0.01 (0.0)	5.13 (0.64)	0.06 (0.01)	264.44 (89.59)	82.07 (24.63)	0.95 (0.05)
	6	-0.70 (0.09)	0.01 (0.0)	3.11 (0.26)	0.01 (0.0)	4.46 (0.80)	0.06 (0.01)	232.53 (46.85)	76.72 (34.10)	0.69 (0.04)
29	1	-0.47 (0.10)	0.01 (0.0)	2.09 (0.39)	0.01 (0.0)	5.87 (1.55)	0.06 (0.01)	313.02 (172.29)	141.84 (72.57)	1.0 (0.06)
	2	-0.70 (0.07)	0.01 (0.0)	2.62 (0.23)	0.01 (0.0)	5.07 (0.54)	0.05 (0.01)	379.74 (162.16)	122.13 (28.97)	0.73 (0.04)
	3	-0.86 (0.12)	0.01 (0.0)	2.94 (0.25)	0.01 (0.0)	4.03 (0.42)	0.05 (0.0)	327.12 (64.62)	100.02 (20.22)	0.61 (0.06)
	4	-0.52 (0.05)	0.01 (0.0)	2.52 (0.26)	0.01 (0.0)	4.35 (0.56)	0.06 (0.0)	278.44 (26.98)	73.75 (16.89)	0.76 (0.05)
	5	-0.90 (0.12)	0.01 (0.0)	2.97 (0.28)	0.01 (0.0)	4.86 (0.81)	0.05 (0.01)	477.16 (205.32)	140.04 (36.59)	0.64 (0.03)
	6	-1.08 (0.07)	0.01 (0.0)	2.88 (0.32)	0.01 (0.0)	4.84 (0.21)	0.04 (0.0)	350.97 (104.49)	158.26 (21.02)	0.56 (0.01)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
31	1	-0.57 (0.11)	0.01 (0.0)	2.89 (0.29)	0.01 (0.0)	5.12 (1.29)	0.07 (0.01)	275.36 (31.95)	70.94 (37.30)	0.93 (0.08)
	2	-0.73 (0.08)	0.01 (0.0)	3.07 (0.75)	0.02 (0.03)	3.95 (0.42)	0.06 (0.01)	291.19 (91.96)	58.62 (11.21)	0.74 (0.08)
	3	-0.90 (0.06)	0.01 (0.0)	2.73 (0.38)	0.01 (0.0)	3.16 (0.41)	0.05 (0.01)	363.99 (89.0)	58.18 (16.82)	0.55 (0.05)
	4	-0.60 (0.04)	0.01 (0.0)	2.55 (0.16)	0.01 (0.0)	4.22 (1.14)	0.06 (0.01)	209.81 (20.87)	65.61 (21.0)	0.79 (0.05)
	5	-0.83 (0.06)	0.01 (0.0)	2.65 (0.28)	0.01 (0.0)	2.95 (0.24)	0.06 (0.01)	344.98 (87.40)	38.38 (6.12)	0.64 (0.03)
	6	-1.32 (0.08)	0.01 (0.0)	2.81 (0.36)	0.0 (0.0)	2.99 (0.39)	0.04 (0.0)	794.46 (335.04)	69.41 (15.75)	0.47 (0.03)
32	1	-0.54 (0.10)	0.01 (0.0)	2.52 (0.12)	0.01 (0.01)	5.68 (0.64)	0.07 (0.01)	230.66 (133.46)	95.16 (24.48)	0.91 (0.08)
	2	-0.57 (0.06)	0.01 (0.0)	2.30 (0.28)	0.01 (0.0)	4.38 (0.70)	0.06 (0.0)	231.51 (56.53)	78.30 (19.42)	0.70 (0.03)
	3	-0.65 (0.09)	0.01 (0.0)	1.94 (0.15)	0.01 (0.0)	3.01 (0.19)	0.06 (0.01)	190.56 (33.87)	51.72 (8.15)	0.56 (0.02)
	4	-0.58 (0.09)	0.01 (0.0)	2.35 (0.13)	0.01 (0.0)	4.42 (0.93)	0.07 (0.01)	221.22 (43.35)	78.42 (45.01)	0.71 (0.05)
	5	-0.71 (0.05)	0.01 (0.0)	2.20 (0.10)	0.02 (0.02)	3.44 (0.46)	0.05 (0.01)	241.82 (79.17)	73.72 (12.31)	0.56 (0.03)
	6	-0.71 (0.09)	0.01 (0.0)	1.97 (0.14)	0.01 (0.0)	3.06 (0.37)	0.05 (0.01)	235.56 (61.93)	61.04 (12.54)	0.54 (0.01)
33	1	-0.40 (0.08)	0.01 (0.0)	2.74 (0.11)	0.01 (0.01)	5.73 (0.50)	0.07 (0.01)	254.91 (114.84)	76.55 (12.21)	1.01 (0.04)
	2	-0.67 (0.11)	0.01 (0.0)	3.07 (0.28)	0.01 (0.0)	4.11 (0.23)	0.07 (0.0)	242.88 (95.43)	70.50 (11.04)	0.73 (0.05)
	3	-1.17 (0.16)	0.01 (0.0)	3.40 (0.23)	0.01 (0.0)	4.29 (0.45)	0.05 (0.01)	327.33 (129.49)	118.95 (26.15)	0.60 (0.03)
	4	-0.51 (0.04)	0.01 (0.0)	2.44 (0.18)	0.01 (0.0)	3.98 (0.61)	0.07 (0.01)	165.15 (17.73)	59.56 (9.91)	0.84 (0.07)
	5	-0.79 (0.04)	0.01 (0.0)	2.75 (0.13)	0.01 (0.0)	3.78 (0.20)	0.06 (0.0)	256.76 (76.0)	73.45 (8.24)	0.65 (0.03)
	6	-1.60 (0.15)	0.01 (0.0)	4.22 (0.17)	0.01 (0.0)	4.33 (0.55)	0.05 (0.0)	433.86 (109.67)	134.71 (36.05)	0.50 (0.04)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
35	1	-0.67	0.01	4.02	0.01	4.22	0.06	445.62	69.16	0.95
		(0.08)	(0.0)	(0.21)	(0.0)	(0.78)	(0.01)	(79.45)	(40.22)	(0.04)
	2	-0.85	0.01	3.67	0.01	3.08	0.06	379.04	52.60	0.73
		(0.07)	(0.0)	(0.21)	(0.0)	(0.66)	(0.0)	(167.95)	(30.28)	(0.02)
	3	-1.22	0.01	3.78	0.01	3.43	0.04	544.81	90.67	0.58
		(0.11)	(0.0)	(0.38)	(0.0)	(0.40)	(0.0)	(213.88)	(20.09)	(0.04)
	4	-0.69	0.01	3.87	0.01	3.31	0.06	365.83	48.94	0.92
		(0.09)	(0.0)	(0.13)	(0.0)	(0.73)	(0.0)	(94.65)	(20.34)	(0.02)
	5	-0.86	0.01	3.70	0.01	2.67	0.06	312.95	42.27	0.63
		(0.11)	(0.0)	(0.15)	(0.0)	(0.34)	(0.01)	(46.06)	(12.25)	(0.02)
	6	-1.28	0.03	2.63	0.01	2.70	0.04	553.47	97.41	0.42
		(1.32)	(0.05)	(0.88)	(0.0)	(1.63)	(0.01)	(279.14)	(15.43)	(0.28)

Note: Force units is $N \cdot J^{-1}$ Loading Rate units is $N \cdot s^{-1} \cdot J^{-1}$;values in parenthesis are standard deviation.

Appendix AH

Male Subject Table Joint Moments

Male subject peak hip, knee and ankle joint moments.

		Hip			Knee			Ankle		
Subj	Cond	Ext	Abd	Ext Rotat	Ext	Add	Int Rotat	Plant Flex	Add	Int Rot
2	1	-0.98	0.15	-0.08	-0.81	-0.10	0.06	-0.58	-0.02	0.03
		(0.16)	(0.07)	(0.02)	(0.14)	(0.02)	(0.02)	(0.06)	(0.01)	(0.01)
	2	-0.69	0.15	-0.06	-0.54	-0.10	0.07	-0.40	-0.02	0.02
		(0.30)	(0.07)	(0.01)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
	3	-0.86	0.15	-0.09	-0.73	-0.10	0.08	-0.31	-0.02	0.02
		(0.53)	(0.07)	(0.03)	(0.19)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)
	4	-0.86	0.15	-0.08	-0.79	-0.10	0.09	-0.62	-0.02	0.03
		(0.11)	(0.07)	(0.01)	(0.07)	(0.02)	(0.01)	(0.04)	(0.01)	(0.01)
	5	-0.81	0.15	-0.08	-0.63	-0.10	0.08	-0.49	-0.02	0.02
		(0.10)	(0.07)	(0.02)	(0.07)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
	6	-0.80	0.15	-0.09	-0.52	-0.10	0.06	-0.35	-0.02	0.02
		(0.22)	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.01)	(0.01)
7	1	-0.94	0.30	-0.16	-0.70	-0.07	0.08	-0.30	-0.02	0.01
		(0.40)	(0.16)	(0.08)	(0.05)	(0.06)	(0.02)	(0.01)	(0.02)	(0.01)
	2	-0.83	0.27	-0.14	-0.55	-0.04	0.04	-0.22	-0.01	0.02
		(0.25)	(0.10)	(0.03)	(0.07)	(0.03)	(0.04)	(0.04)	(0.01)	(0.02)
	3	-0.62	0.32	-0.08	-0.50	-0.05	0.05	-0.19	-0.02	0.02
		(0.19)	(0.15)	(0.03)	(0.10)	(0.04)	(0.02)	(0.01)	(0.01)	(0.01)
	4	-0.85	0.32	-0.11	-0.72	-0.07	0.07	-0.34	-0.02	0.03
		(0.27)	(0.05)	(0.02)	(0.06)	(0.06)	(0.02)	(0.03)	(0.02)	(0.01)
	5	-0.87	0.34	-0.11	-0.59	-0.08	0.08	-0.29	-0.01	0.02
		(0.15)	(0.06)	(0.04)	(0.03)	(0.05)	(0.03)	(0.04)	(0.01)	(0.01)
	6	-1.03	0.31	-0.11	-0.50	-0.03	0.02	-0.19	-0.01	0.01
		(0.24)	(0.07)	(0.04)	(0.04)	(0.01)	(0.02)	(0.03)	(0.01)	(0.01)
9	1	-0.74	0.16	-0.07	-0.71	-0.17	0.11	-0.39	-0.02	0.02
		(0.20)	(0.02)	(0.02)	(0.19)	(0.05)	(0.03)	(0.08)	(0.0)	(0.01)
	2	-0.85	0.15	-0.10	-0.74	-0.15	0.09	-0.29	-0.04	0.01
		(0.25)	(0.09)	(0.02)	(0.17)	(0.05)	(0.02)	(0.03)	(0.04)	(0.02)
	3	-0.82	0.12	-0.09	-0.54	-0.14	0.09	-0.22	-0.05	0.01
		(0.18)	(0.04)	(0.02)	(0.12)	(0.06)	(0.05)	(0.02)	(0.04)	(0.01)
	4	-0.75	0.18	-0.10	-0.76	-0.23	0.15	-0.42	-0.02	0.01
		(0.06)	(0.08)	(0.01)	(0.12)	(0.03)	(0.02)	(0.06)	(0.03)	(0.01)
	5	-0.64	0.14	-0.09	-0.56	-0.17	0.11	-0.33	-0.03	0.01
		(0.10)	(0.03)	(0.01)	(0.14)	(0.03)	(0.02)	(0.04)	(0.04)	(0.01)
	6	-0.63	0.12	-0.10	-0.43	-0.16	0.11	-0.28	-0.03	0.01
		(0.16)	(0.05)	(0.02)	(0.05)	(0.04)	(0.02)	(0.02)	(0.02)	(0.01)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rot
11	1	-1.31 (0.73)	0.42 (0.21)	-0.07 (0.02)	-0.59 (0.09)	-0.13 (0.04)	0.06 (0.02)	-0.25 (0.04)	0.01 (0.02)	0.01 (0.01)
	2	-0.33 (0.15)	0.11 (0.12)	-0.08 (0.05)	-0.27 (0.17)	-0.04 (0.03)	0.06 (0.07)	-0.17 (0.10)	0.0 (0.01)	0.01 (0.01)
	3	-0.30 (0.13)	0.21 (0.13)	-0.03 (0.01)	-0.34 (0.04)	-0.06 (0.02)	0.03 (0.02)	-0.19 (0.03)	0.01 (0.0)	0.01 (0.01)
	4	-0.95 (0.13)	0.39 (0.10)	-0.06 (0.01)	-0.60 (0.04)	-0.13 (0.03)	0.06 (0.01)	-0.26 (0.03)	0.0 (0.01)	0.01 (0.01)
	5	-0.87 (0.45)	0.35 (0.15)	-0.06 (0.02)	-0.48 (0.08)	-0.10 (0.02)	0.05 (0.02)	-0.24 (0.06)	0.0 (0.01)	0.01 (0.0)
	6	-0.95 (0.31)	0.35 (0.07)	-0.08 (0.06)	-0.40 (0.02)	-0.06 (0.01)	0.03 (0.01)	-0.18 (0.02)	0.0 (0.01)	0.01 (0.01)
18	1	-0.80 (0.34)	0.13 (0.04)	-0.07 (0.02)	-0.61 (0.07)	-0.06 (0.01)	0.01 (0.01)	-0.38 (0.07)	-0.01 (0.0)	0.01 (0.01)
	2	-0.89 (0.25)	0.13 (0.03)	-0.06 (0.03)	-0.56 (0.13)	-0.10 (0.05)	0.03 (0.02)	-0.28 (0.02)	-0.01 (0.02)	0.02 (0.01)
	3	-1.02 (0.31)	0.19 (0.04)	-0.06 (0.03)	-0.68 (0.32)	-0.07 (0.02)	0.02 (0.01)	-0.20 (0.01)	-0.01 (0.01)	0.02 (0.01)
	4	-1.02 (0.31)	0.20 (0.14)	-0.08 (0.04)	-0.73 (0.10)	-0.13 (0.02)	0.05 (0.02)	-0.44 (0.03)	-0.02 (0.01)	0.02 (0.02)
	5	-0.88 (0.24)	0.10 (0.02)	-0.07 (0.01)	-0.62 (0.06)	-0.12 (0.02)	0.04 (0.02)	-0.37 (0.05)	-0.02 (0.01)	0.01 (0.01)
	6	-0.82 (0.32)	0.23 (0.10)	-0.05 (0.04)	-0.69 (0.17)	-0.06 (0.02)	0.03 (0.01)	-0.25 (0.10)	-0.01 (0.01)	0.03 (0.02)
22	1	-0.65 (0.10)	0.13 (0.03)	-0.18 (0.03)	-0.49 (0.09)	-0.12 (0.01)	0.04 (0.01)	-0.44 (0.04)	-0.01 (0.01)	0.01 (0.01)
	2	-0.68 (0.05)	0.17 (0.04)	-0.10 (0.04)	-0.52 (0.15)	-0.06 (0.01)	0.02 (0.01)	-0.27 (0.02)	-0.01 (0.01)	0.01 (0.02)
	3	-0.53 (0.22)	0.16 (0.06)	-0.06 (0.03)	-0.32 (0.07)	-0.04 (0.01)	0.02 (0.01)	-0.22 (0.01)	0.02 (0.01)	-0.01 (0.0)
	4	-0.95 (0.36)	0.13 (0.04)	-0.15 (0.05)	-0.45 (0.05)	-0.11 (0.03)	0.03 (0.02)	-0.34 (0.06)	-0.01 (0.02)	0.01 (0.01)
	5	-0.77 (0.30)	0.16 (0.04)	-0.09 (0.03)	-0.58 (0.21)	-0.05 (0.02)	0.01 (0.01)	-0.24 (0.02)	-0.01 (0.02)	0.01 (0.02)
	6	-0.58 (0.13)	0.15 (0.03)	-0.09 (0.06)	-0.43 (0.11)	-0.04 (0.02)	0.01 (0.01)	-0.22 (0.03)	0.0 (0.02)	0.0 (0.02)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rot
24	1	-0.66	0.13	-0.07	-0.54	-0.16	0.07	-0.57	0.02	-0.02
		(0.08)	(0.04)	(0.01)	(0.03)	(0.04)	(0.02)	(0.03)	(0.01)	(0.01)
	2	-0.87	0.17	-0.10	-0.51	-0.10	0.08	-0.34	-0.02	0.01
		(0.30)	(0.16)	(0.08)	(0.05)	(0.03)	(0.03)	(0.02)	(0.08)	(0.01)
	3	-0.36	0.17	-0.05	-0.56	-0.08	0.03	-0.26	0.0	0.01
		(0.32)	(0.10)	(0.01)	(0.12)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
	4	-0.55	0.16	-0.08	-0.77	-0.20	0.09	-0.60	0.01	0.0
		(0.28)	(0.06)	(0.02)	(0.07)	(0.03)	(0.02)	(0.03)	(0.03)	(0.01)
	5	-0.59	0.16	-0.08	-0.54	-0.16	0.07	-0.48	0.0	0.0
		(0.04)	(0.04)	(0.01)	(0.04)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
	6	-0.59	0.12	-0.06	-0.50	-0.09	0.06	-0.39	0.01	0.01
		(0.11)	(0.02)	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
25	1	-0.71	0.20	-0.09	-0.65	-0.09	0.04	-0.48	-0.01	0.01
		(0.09)	(0.05)	(0.02)	(0.04)	(0.05)	(0.02)	(0.04)	(0.02)	(0.01)
	2	-0.58	0.16	-0.08	-0.47	-0.05	0.03	-0.33	-0.01	0.0
		(0.08)	(0.05)	(0.03)	(0.06)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
	3	-0.44	0.15	-0.07	-0.47	-0.05	0.01	-0.26	0.0	0.02
		(0.07)	(0.02)	(0.01)	(0.11)	(0.02)	(0.01)	(0.01)	(0.03)	(0.0)
	4	-0.80	0.16	-0.15	-0.64	-0.06	0.03	-0.45	0.0	0.0
		(0.10)	(0.04)	(0.03)	(0.04)	(0.01)	(0.01)	(0.05)	(0.02)	(0.0)
	5	-0.52	0.14	-0.07	-0.45	-0.03	0.02	-0.30	-0.01	0.01
		(0.10)	(0.03)	(0.03)	(0.02)	(0.02)	(0.01)	(0.11)	(0.0)	(0.0)
	6	-0.44	0.16	-0.08	-0.41	-0.04	0.02	-0.26	-0.01	0.02
		(0.10)	(0.04)	(0.02)	(0.05)	(0.02)	(0.01)	(0.01)	(0.02)	(0.0)
26	1	-0.66	0.28	-0.03	-0.59	-0.12	0.06	-0.52	0.01	-0.01
		(0.08)	(0.02)	(0.01)	(0.03)	(0.02)	(0.01)	(0.06)	(0.0)	(0.0)
	2	-0.71	0.37	-0.04	-0.42	-0.08	0.05	-0.37	0.01	0.0
		(0.15)	(0.05)	(0.02)	(0.12)	(0.03)	(0.04)	(0.03)	(0.03)	(0.0)
	3	-0.92	0.37	-0.05	-0.55	-0.08	0.05	-0.30	0.01	0.01
		(0.35)	(0.10)	(0.04)	(0.12)	(0.02)	(0.02)	(0.06)	(0.03)	(0.01)
	4	-1.17	0.45	-0.03	-0.56	-0.10	0.05	-0.41	-0.03	0.01
		(0.22)	(0.09)	(0.02)	(0.05)	(0.03)	(0.02)	(0.04)	(0.02)	(0.01)
	5	-0.69	0.34	-0.02	-0.43	-0.08	0.05	-0.38	0.01	0.0
		(0.12)	(0.08)	(0.01)	(0.03)	(0.03)	(0.01)	(0.02)	(0.0)	(0.0)
	6	-0.74	0.33	-0.04	-0.43	-0.07	0.06	-0.28	0.0	0.0
		(0.19)	(0.11)	(0.04)	(0.09)	(0.03)	(0.02)	(0.05)	(0.0)	(0.01)

Continued.

		Hip			Knee			Ankle		
Subj	Cond	Ext	Abd	Ext Rotat	Ext	Add	Int Rotat	Plant Flex	Add	Int Rot
27	1	-1.07 (0.37)	0.45 (0.16)	-0.17 (0.04)	-0.67 (0.09)	-0.21 (0.08)	0.13 (0.06)	-0.27 (0.04)	-0.02 (0.04)	0.08 (0.03)
	2	-0.96 (0.37)	0.32 (0.10)	-0.11 (0.02)	-0.48 (0.05)	-0.26 (0.06)	0.08 (0.03)	-0.21 (0.03)	-0.02 (0.04)	0.04 (0.01)
	3	-0.64 (0.22)	0.33 (0.10)	-0.09 (0.02)	-0.47 (0.25)	-0.20 (0.10)	0.07 (0.02)	-0.17 (0.02)	-0.01 (0.02)	0.04 (0.0)
	4	-1.75 (0.44)	0.26 (0.12)	-0.20 (0.04)	-0.76 (0.12)	-0.24 (0.07)	0.10 (0.05)	-0.34 (0.10)	0.04 (0.02)	0.07 (0.04)
	5	-1.53 (0.36)	0.49 (0.16)	-0.17 (0.04)	-0.75 (0.04)	-0.26 (0.07)	0.12 (0.06)	-0.26 (0.03)	0.01 (0.02)	0.07 (0.03)
	6	-1.15 (0.24)	0.44 (0.14)	-0.14 (0.01)	-0.61 (0.07)	-0.18 (0.10)	0.08 (0.01)	-0.21 (0.02)	0.01 (0.05)	0.05 (0.01)
28	1	-0.43 (0.16)	0.35 (0.16)	-0.08 (0.07)	-0.47 (0.20)	-0.09 (0.04)	0.04 (0.02)	-0.34 (0.19)	-0.04 (0.02)	0.05 (0.06)
	2	-0.56 (0.15)	0.27 (0.08)	-0.08 (0.01)	-0.47 (0.05)	-0.03 (0.02)	0.02 (0.02)	-0.32 (0.05)	-0.04 (0.02)	0.02 (0.01)
	3	-0.42 (0.10)	0.23 (0.05)	-0.05 (0.02)	-0.50 (0.12)	-0.03 (0.01)	0.03 (0.01)	-0.24 (0.03)	-0.03 (0.01)	0.02 (0.01)
	4	-0.56 (0.14)	0.24 (0.11)	-0.08 (0.04)	-0.64 (0.08)	-0.07 (0.01)	0.05 (0.01)	-0.47 (0.03)	-0.05 (0.02)	0.01 (0.01)
	5	-0.47 (0.15)	0.25 (0.08)	-0.08 (0.04)	-0.54 (0.03)	-0.10 (0.02)	0.05 (0.02)	-0.37 (0.04)	-0.03 (0.01)	0.01 (0.01)
	6	-0.56 (0.19)	0.24 (0.08)	-0.09 (0.05)	-0.49 (0.07)	-0.04 (0.02)	0.02 (0.01)	-0.32 (0.03)	-0.03 (0.02)	-0.01 (0.0)
29	1	-0.95 (0.39)	0.49 (0.22)	-0.06 (0.03)	-0.62 (0.06)	-0.20 (0.04)	0.04 (0.02)	-0.37 (0.07)	-0.02 (0.01)	0.01 (0.01)
	2	-0.72 (0.19)	0.43 (0.10)	-0.04 (0.01)	-0.46 (0.02)	-0.15 (0.02)	0.04 (0.02)	-0.32 (0.05)	-0.07 (0.06)	0.01 (0.01)
	3	-0.64 (0.09)	0.42 (0.07)	-0.04 (0.02)	-0.49 (0.07)	-0.14 (0.03)	0.05 (0.01)	-0.23 (0.03)	-0.02 (0.01)	0.0 (0.01)
	4	-0.66 (0.06)	0.37 (0.05)	-0.06 (0.03)	-0.53 (0.01)	-0.16 (0.0)	0.05 (0.01)	-0.30 (0.01)	-0.03 (0.01)	-0.01 (0.01)
	5	-0.78 (0.28)	0.55 (0.17)	-0.07 (0.01)	-0.49 (0.09)	-0.16 (0.05)	0.04 (0.01)	-0.22 (0.04)	-0.03 (0.01)	0.0 (0.01)
	6	-0.81 (0.16)	0.53 (0.12)	-0.08 (0.03)	-0.51 (0.21)	-0.13 (0.05)	0.03 (0.01)	-0.21 (0.03)	-0.04 (0.05)	0.0 (0.01)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rot
31	1	-0.68 (0.11)	0.19 (0.03)	-0.10 (0.04)	-0.58 (0.05)	-0.20 (0.02)	0.09 (0.02)	-0.55 (0.14)	-0.05 (0.05)	0.02 (0.02)
	2	-0.52 (0.12)	0.07 (0.08)	-0.12 (0.05)	-0.50 (0.02)	-0.15 (0.04)	0.06 (0.03)	-0.39 (0.04)	-0.04 (0.02)	0.01 (0.01)
	3	-0.45 (0.07)	0.14 (0.10)	-0.08 (0.02)	-0.51 (0.18)	-0.12 (0.03)	0.04 (0.01)	-0.27 (0.03)	-0.03 (0.01)	-0.01 (0.01)
	4	-0.61 (0.22)	0.12 (0.04)	-0.08 (0.02)	-0.46 (0.08)	-0.16 (0.02)	0.07 (0.02)	-0.38 (0.08)	-0.04 (0.01)	0.04 (0.03)
	5	-0.48 (0.15)	0.13 (0.10)	-0.11 (0.05)	-0.46 (0.06)	-0.19 (0.04)	0.08 (0.03)	-0.31 (0.04)	-0.03 (0.04)	0.0 (0.01)
	6	-0.46 (0.08)	0.03 (0.01)	-0.10 (0.02)	-0.33 (0.02)	-0.13 (0.04)	0.03 (0.01)	-0.24 (0.02)	-0.02 (0.01)	0.0 (0.0)
32	1	-0.79 (0.09)	0.21 (0.09)	-0.07 (0.03)	-0.51 (0.06)	-0.34 (0.06)	0.10 (0.04)	-0.48 (0.06)	-0.05 (0.03)	0.02 (0.02)
	2	-0.45 (0.21)	0.19 (0.09)	-0.06 (0.03)	-0.39 (0.02)	-0.23 (0.02)	0.05 (0.01)	-0.36 (0.02)	0.04 (0.03)	0.0 (0.02)
	3	-0.42 (0.09)	0.13 (0.05)	-0.04 (0.01)	-0.33 (0.03)	-0.19 (0.02)	0.06 (0.02)	-0.32 (0.03)	-0.03 (0.02)	0.02 (0.01)
	4	-0.70 (0.29)	0.21 (0.15)	-0.05 (0.01)	-0.44 (0.06)	-0.28 (0.03)	0.07 (0.01)	-0.37 (0.06)	-0.01 (0.04)	0.0 (0.01)
	5	-0.54 (0.09)	0.24 (0.10)	-0.05 (0.01)	-0.45 (0.07)	-0.21 (0.04)	0.06 (0.01)	-0.31 (0.02)	-0.01 (0.0)	0.01 (0.01)
	6	-0.40 (0.10)	0.16 (0.08)	-0.05 (0.01)	-0.38 (0.05)	-0.20 (0.03)	0.05 (0.01)	-0.30 (0.02)	0.0 (0.01)	0.01 (0.01)
33	1	-0.53 (0.05)	0.16 (0.04)	-0.09 (0.04)	-0.54 (0.04)	-0.12 (0.05)	0.06 (0.02)	-0.57 (0.02)	0.0 (0.01)	0.02 (0.01)
	2	-0.56 (0.08)	0.23 (0.03)	-0.09 (0.02)	-0.52 (0.07)	-0.10 (0.01)	0.06 (0.01)	-0.27 (0.04)	-0.01 (0.01)	0.01 (0.01)
	3	-0.29 (0.13)	0.26 (0.09)	-0.07 (0.02)	-0.49 (0.16)	-0.06 (0.06)	0.06 (0.02)	-0.21 (0.03)	-0.01 (0.01)	0.01 (0.01)
	4	-0.50 (0.06)	0.21 (0.04)	-0.06 (0.02)	-0.48 (0.03)	-0.10 (0.03)	0.06 (0.02)	-0.34 (0.02)	-0.01 (0.01)	0.02 (0.01)
	5	-0.47 (0.04)	0.20 (0.01)	-0.06 (0.02)	-0.41 (0.08)	-0.09 (0.03)	0.06 (0.02)	-0.27 (0.01)	0.0 (0.02)	0.0 (0.01)
	6	-0.19 (0.02)	0.20 (0.08)	-0.04 (0.01)	-0.50 (0.26)	-0.07 (0.04)	0.04 (0.01)	-0.19 (0.02)	-0.02 (0.03)	0.02 (0.02)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rot
35	1	-0.32	0.13	-0.07	-0.48	-0.10	0.03	-0.35	-0.01	0.0
		(0.04)	(0.06)	(0.02)	(0.02)	(0.01)	(0.01)	(0.03)	(0.04)	(0.01)
	2	-0.38	0.25	-0.05	-0.40	-0.11	0.05	-0.25	-0.04	0.02
		(0.09)	(0.12)	(0.01)	(0.16)	(0.05)	(0.01)	(0.01)	(0.04)	(0.01)
	3	-0.26	0.23	-0.05	-0.55	-0.06	0.03	-0.21	-0.03	0.0
		(0.15)	(0.06)	(0.04)	(0.32)	(0.02)	(0.02)	(0.01)	(0.03)	(0.01)
	4	-0.50	0.28	-0.08	-0.51	-0.10	0.04	-0.29	-0.03	0.03
		(0.11)	(0.15)	(0.02)	(0.12)	(0.03)	(0.01)	(0.02)	(0.05)	(0.02)
	5	-0.41	0.25	-0.06	-0.48	-0.08	0.04	-0.23	-0.06	0.01
		(0.11)	(0.09)	(0.02)	(0.23)	(0.03)	(0.02)	(0.03)	(0.04)	(0.01)
	6	-0.36	0.20	-0.04	-0.36	-0.07	0.03	-0.12	-0.03	0.01
		(0.24)	(0.12)	(0.02)	(0.27)	(0.04)	(0.02)	(0.08)	(0.03)	(0.01)

Note: Peak moment unit is N•m•J^{-1}; values in parenthesis are standard deviation.

Appendix AI

Male Subject Table Eccentric Joint Work

Male resultant hip, knee, and ankle joint eccentric work.

Subject	Condition	Hip	Knee	Ankle
2	1	-0.04 (0.02)	-0.25 (0.03)	-0.21 (0.03)
	2	-0.03 (0.01)	-0.24 (0.03)	-0.16 (0.01)
	3	-0.06 (0.03)	-0.28 (0.04)	-0.11 (0.02)
	4	-0.02 (0.01)	-0.23 (0.02)	-0.20 (0.01)
	5	-0.04 (0.02)	-0.21 (0.03)	-0.19 (0.0)
	6	-0.07 (0.02)	-0.24 (0.01)	-0.13 (0.02)
7	1	-0.07 (0.03)	-0.52 (0.04)	-0.14 (0.01)
	2	-0.06 (0.05)	-0.39 (0.02)	-0.10 (0.03)
	3	-0.09 (0.03)	-0.39 (0.04)	-0.11 (0.02)
	4	-0.09 (0.03)	-0.60 (0.03)	-0.15 (0.02)
	5	-0.07 (0.04)	-0.47 (0.01)	-0.15 (0.02)
	6	-0.14 (0.03)	-0.41 (0.03)	-0.11 (0.02)
9	1	-0.10 (0.04)	-0.31 (0.04)	-0.20 (0.05)
	2	-0.13 (0.04)	-0.28 (0.03)	-0.15 (0.02)
	3	-0.17 (0.03)	-0.26 (0.01)	-0.14 (0.02)
	4	-0.07 (0.02)	-0.27 (0.03)	-0.21 (0.03)
	5	-0.10 (0.04)	-0.24 (0.05)	-0.19 (0.01)
	6	-0.13 (0.04)	-0.28 (0.03)	-0.15 (0.02)

Continued.

Subject	Condition	Hip	Knee	Ankle
11	1	-0.15 (0.03)	-0.37 (0.04)	-0.13 (0.04)
	2	-0.13 (0.21)	-0.22 (0.13)	-0.09 (0.06)
	3	-0.12 (0.02)	-0.26 (0.02)	-0.10 (0.02)
	4	-0.11 (0.03)	-0.36 (0.04)	-0.16 (0.01)
	5	-0.16 (0.02)	-0.32 (0.03)	-0.13 (0.03)
	6	-0.15 (0.04)	-0.25 (0.02)	-0.11 (0.02)
18	1	-0.10 (0.01)	-0.20 (0.03)	-0.13 (0.03)
	2	-0.14 (0.04)	-0.25 (0.03)	-0.14 (0.02)
	3	-0.14 (0.01)	-0.23 (0.03)	-0.10 (0.01)
	4	-0.11 (0.02)	-0.26 (0.04)	-0.18 (0.06)
	5	-0.12 (0.02)	-0.24 (0.02)	-0.17 (0.03)
	6	-0.15 (0.02)	-0.24 (0.03)	-0.15 (0.02)
22	1	-0.18 (0.05)	-0.24 (0.03)	-0.21 (0.02)
	2	-0.21 (0.03)	-0.25 (0.02)	-0.14 (0.01)
	3	-0.21 (0.02)	-0.21 (0.01)	-0.13 (0.01)
	4	-0.22 (0.03)	-0.26 (0.02)	-0.15 (0.03)
	5	-0.21 (0.04)	-0.26 (0.03)	-0.12 (0.01)
	6	-0.18 (0.02)	-0.21 (0.02)	-0.11 (0.01)

Continued.

Subject	Condition	Hip	Knee	Ankle
24	1	-0.05 (0.01)	-0.25 (0.05)	-0.30 (0.02)
	2	-0.17 (0.03)	-0.36 (0.03)	-0.16 (0.03)
	3	-0.20 (0.02)	-0.34 (0.03)	-0.14 (0.02)
	4	-0.05 (0.0)	-0.36 (0.11)	-0.34 (0.02)
	5	-0.03 (0.01)	-0.25 (0.06)	-0.27 (0.01)
	6	-0.13 (0.02)	-0.35 (0.05)	-0.22 (0.01)
25	1	-0.02 (0.02)	-0.27 (0.08)	-0.26 (0.02)
	2	-0.06 (0.02)	-0.26 (0.07)	-0.19 (0.01)
	3	-0.09 (0.02)	-0.32 (0.03)	-0.14 (0.02)
	4	-0.02 (0.01)	-0.26 (0.03)	-0.22 (0.02)
	5	-0.05 (0.01)	-0.23 (0.03)	-0.19 (0.02)
	6	-0.10 (0.02)	-0.35 (0.03)	-0.14 (0.02)
26	1	0.0 (0.02)	-0.13 (0.03)	-0.25 (0.05)
	2	0.0 (0.01)	-0.12 (0.08)	-0.15 (0.04)
	3	-0.04 (0.01)	-0.19 (0.03)	-0.12 (0.03)
	4	-0.07 (0.02)	-0.19 (0.01)	-0.21 (0.05)
	5	-0.01 (0.01)	-0.17 (0.03)	-0.18 (0.03)
	6	-0.03 (0.01)	-0.18 (0.02)	-0.14 (0.04)

Continued.

Subject	Condition	Hip	Knee	Ankle
27	1	-0.08 (0.07)	-0.26 (0.04)	-0.09 (0.03)
	2	-0.08 (0.02)	-0.21 (0.03)	-0.08 (0.03)
	3	-0.11 (0.02)	-0.21 (0.01)	-0.10 (0.01)
	4	-0.10 (0.04)	-0.22 (0.04)	-0.10 (0.04)
	5	-0.12 (0.02)	-0.29 (0.04)	-0.09 (0.03)
	6	-0.08 (0.05)	-0.22 (0.14)	-0.08 (0.02)
28	1	-0.03 (0.07)	-0.23 (0.13)	-0.21 (0.12)
	2	-0.05 (0.02)	-0.23 (0.02)	-0.18 (0.03)
	3	-0.08 (0.04)	-0.26 (0.02)	-0.14 (0.02)
	4	-0.02 (0.02)	-0.25 (0.04)	-0.29 (0.03)
	5	-0.05 (0.01)	-0.28 (0.02)	-0.23 (0.03)
	6	-0.06 (0.04)	-0.26 (0.08)	-0.16 (0.08)
29	1	-0.11 (0.10)	-0.34 (0.13)	-0.15 (0.01)
	2	-0.04 (0.01)	-0.25 (0.03)	-0.14 (0.02)
	3	-0.08 (0.02)	-0.30 (0.03)	-0.12 (0.01)
	4	-0.03 (0.01)	-0.20 (0.05)	-0.16 (0.02)
	5	-0.07 (0.02)	-0.34 (0.09)	-0.13 (0.02)
	6	-0.09 (0.02)	-0.32 (0.04)	-0.12 (0.02)

Continued.

Subject	Condition	Hip	Knee	Ankle
31	1	-0.02 (0.02)	-0.17 (0.03)	-0.16 (0.06)
	2	-0.02 (0.02)	-0.19 (0.03)	-0.14 (0.04)
	3	-0.04 (0.01)	-0.20 (0.02)	-0.13 (0.0)
	4	-0.04 (0.03)	-0.19 (0.03)	-0.14 (0.04)
	5	-0.04 (0.02)	-0.17 (0.02)	-0.08 (0.07)
	6	-0.11 (0.02)	-0.19 (0.02)	-0.11 (0.01)
32	1	-0.07 (0.06)	-0.12 (0.01)	-0.21 (0.03)
	2	-0.09 (0.02)	-0.18 (0.04)	-0.18 (0.02)
	3	-0.08 (0.01)	-0.19 (0.03)	-0.15 (0.01)
	4	-0.08 (0.04)	-0.22 (0.03)	-0.17 (0.04)
	5	-0.10 (0.03)	-0.21 (0.01)	-0.14 (0.01)
	6	-0.12 (0.01)	-0.19 (0.03)	-0.14 (0.01)
33	1	-0.02 (0.01)	-0.11 (0.03)	-0.28 (0.03)
	2	-0.04 (0.0)	-0.20 (0.02)	-0.18 (0.01)
	3	-0.06 (0.02)	-0.23 (0.04)	-0.13 (0.03)
	4	-0.04 (0.01)	-0.20 (0.05)	-0.20 (0.01)
	5	-0.05 (0.01)	-0.16 (0.03)	-0.16 (0.02)
	6	-0.05 (0.02)	-0.17 (0.02)	-0.12 (0.01)

Continued.

Subject	Condition	Hip	Knee	Ankle
35	1	-0.16 (0.02)	-0.39 (0.04)	-0.20 (0.01)
	2	-0.13 (0.01)	-0.31 (0.02)	-0.15 (0.01)
	3	-0.10 (0.02)	-0.27 (0.03)	-0.12 (0.02)
	4	-0.15 (0.02)	-0.40 (0.02)	-0.18 (0.03)
	5	-0.11 (0.02)	-0.29 (0.02)	-0.12 (0.02)
	6	-0.11 (0.02)	-0.22 (0.03)	-0.08 (0.02)

Note: Work units is $J{\bullet}PE^{-1}$;values in parenthesis are standard deviation.

Appendix AJ

Female Subject Table Right Ankle Angle

Female subject right ankle angle data

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
1	1	-8.72 (0.95)	35.17 (1.59)	43.89 (1.94)	-8.10 (2.47)	-17.38 (2.94)	-101.94 (1.51)	-4.65 (1.08)
	2	-11.05 (2.79)	34.81 (1.30)	45.87 (3.63)	-4.76 (0.74)	-15.24 (2.48)	-102.86 (1.89)	-6.90 (2.46)
	3	-8.99 (2.48)	32.21 (1.73)	41.19 (2.52)	-7.16 (2.0)	-17.80 (1.77)	-103.14 (1.28)	-6.28 (0.71)
	4	-11.84 (3.30)	34.20 (2.01)	45.74 (3.95)	-6.98 (2.29)	-16.03 (1.83)	-101.60 (0.97)	-4.89 (1.68)
	5	-14.43 (0.91)	30.61 (0.81)	41.33 (5.13)	-5.31 (0.94)	-14.84 (1.67)	-101.88 (0.96)	-9.77 (2.33)
	6	-9.46 (3.0)	34.74 (1.15)	44.20 (3.27)	-8.20 (1.67)	-16.55 (2.0)	-104.04 (1.58)	-6.97 (1.68)
2	1	-18.51 (2.09)	28.55 (2.0)	47.06 (1.86)	-9.77 (1.54)	-19.59 (3.78)	-104.25 (0.72)	-10.08 (1.86)
	2	-16.31 (1.65)	32.39 (2.60)	48.48 (3.22)	-9.11 (1.49)	-16.49 (6.04)	-102.93 (2.32)	-7.13 (2.10)
	3	-18.21 (4.83)	33.78 (1.04)	51.99 (5.32)	-9.70 (1.06)	-20.02 (1.17)	-100.29 (2.57)	-11.29 (2.36)
	4	-18.93 (3.14)	27.92 (2.78)	45.37 (8.63)	-4.32 (1.38)	-15.25 (4.69)	-102.64 (1.60)	-7.63 (1.98)
	5	-12.67 (3.59)	29.13 (2.15)	41.81 (5.66)	-8.54 (1.57)	-21.47 (2.13)	-104.10 (1.73)	-5.14 (3.27)
	6	-18.10 (3.18)	29.38 (1.84)	44.52 (8.72)	-5.22 (1.75)	-14.36 (3.29)	-98.86 (1.97)	-10.48 (1.45)
3	1	-17.71 (3.63)	29.24 (2.04)	43.95 (10.12)	-8.27 (1.01)	-13.09 (1.68)	-100.0 (0.81)	-10.66 (1.99)
	2	-15.77 (1.04)	25.46 (1.82)	39.47 (4.06)	-9.52 (1.35)	-6.97 (3.89)	-97.31 (1.36)	-8.53 (1.76)
	3	-15.34 (2.81)	25.71 (0.97)	41.04 (2.96)	-10.78 (1.45)	-11.94 (1.18)	-98.58 (0.28)	-8.85 (1.60)
	4	-18.03 (0.79)	29.63 (1.24)	47.66 (1.31)	-7.54 (0.71)	-12.41 (2.30)	-99.79 (1.0)	-10.23 (1.49)
	5	-15.91 (1.44)	28.84 (0.74)	44.02 (2.63)	-8.69 (0.47)	-11.66 (1.80)	-98.30 (0.63)	-8.19 (2.07)
	6	-15.62 (2.32)	27.79 (3.05)	43.41 (2.79)	-9.09 (1.33)	-11.50 (2.12)	-99.31 (2.01)	-10.77 (2.01)

Continued.

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
4	1	-14.94 (2.04)	33.27 (1.76)	48.20 (1.15)	-3.98 (1.29)	-13.23 (1.07)	-96.74 (0.75)	-10.86 (1.85)
	2	-15.94 (3.57)	32.42 (1.99)	48.36 (2.30)	-3.96 (2.05)	-12.06 (2.83)	-98.12 (1.23)	-11.69 (1.05)
	3	-15.37 (4.36)	32.57 (0.96)	47.95 (4.26)	-3.73 (2.07)	-12.53 (1.83)	-97.55 (1.29)	-11.45 (2.82)
	4	0.43 (5.12)	34.03 (1.42)	33.60 (3.92)	-4.02 (0.54)	-13.57 (1.47)	-97.65 (0.75)	-11.79 (1.76)
	5	-13.71 (2.87)	33.94 (0.91)	47.66 (3.39)	-4.94 (1.11)	-14.50 (1.78)	-98.03 (1.0)	-11.20 (1.57)
	6	-17.45 (1.93)	32.37 (1.42)	49.82 (2.0)	-3.80 (1.0)	-11.62 (1.80)	-97.94 (0.83)	-12.28 (0.60)
6	1	-9.35 (1.54)	27.50 (0.96)	36.86 (1.97)	2.70 (0.86)	-0.86 (1.03)	-92.63 (2.48)	-4.47 (2.13)
	2	-12.44 (3.88)	26.99 (0.81)	35.11 (4.98)	2.73 (2.34)	5.01 (4.19)	-83.75 (1.59)	-3.68 (1.41)
	3	-10.32 (4.23)	25.27 (1.64)	35.58 (4.08)	1.99 (1.11)	-0.82 (2.10)	-92.55 (1.56)	-3.50 (0.89)
	4	-4.63 (2.70)	22.14 (1.50)	26.77 (2.65)	-0.43 (0.55)	-1.45 (1.18)	-96.17 (0.64)	-6.38 (1.28)
	5	-15.34 (2.60)	24.07 (1.70)	38.23 (3.50)	0.81 (1.75)	2.69 (3.53)	-86.29 (1.80)	-3.37 (1.26)
	6	-14.69 (2.36)	24.83 (0.91)	33.40 (4.99)	-0.14 (1.44)	1.38 (1.91)	-86.13 (0.97)	-4.62 (2.50)
7	1	-10.58 (4.69)	33.88 (0.44)	44.27 (4.36)	-5.91 (1.17)	-15.35 (0.84)	-101.11 (2.16)	-3.60 (2.46)
	2	-12.93 (4.29)	33.82 (1.26)	46.01 (5.13)	-6.78 (2.09)	-16.48 (2.08)	-98.55 (0.66)	-3.27 (1.71)
	3	-13.80 (2.77)	31.19 (2.39)	44.95 (1.06)	-6.57 (1.71)	-13.15 (4.01)	-102.19 (2.90)	-7.84 (6.16)
	4	-1.88 (8.92)	34.62 (1.26)	36.50 (9.53)	-5.25 (0.85)	-12.13 (2.29)	-98.73 (1.99)	-2.81 (1.50)
	5	-14.39 (0.99)	31.63 (2.09)	46.02 (2.30)	-3.95 (2.10)	-12.82 (1.53)	-100.75 (1.61)	-4.21 (1.65)
	6	-19.70 (3.72)	31.27 (0.78)	50.97 (3.80)	-7.07 (2.80)	-14.48 (3.62)	-100.84 (1.23)	-5.45 (1.37)

Continued.

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
8	1	-24.37 (3.71)	30.89 (0.97)	55.26 (4.62)	-12.53 (2.44)	-26.65 (2.70)	-108.76 (1.21)	-10.85 (1.59)
	2	-24.02 (6.51)	29.58 (1.36)	53.59 (6.41)	-14.48 (1.84)	-28.61 (1.26)	-111.57 (1.22)	-13.03 (2.82)
	3	-21.94 (3.13)	26.30 (1.49)	48.24 (3.11)	-16.31 (2.98)	-27.45 (1.63)	-111.78 (2.60)	-11.98 (2.73)
	4	-22.90 (2.07)	31.05 (2.20)	53.95 (2.94)	-12.98 (1.65)	-26.49 (2.46)	-108.19 (2.12)	-12.81 (2.0)
	5	-22.19 (2.65)	29.47 (1.35)	51.72 (2.36)	-13.59 (1.42)	-27.86 (2.52)	-110.21 (1.52)	-10.42 (1.17)
	6	-21.56 (3.03)	29.66 (0.84)	51.22 (3.21)	-15.50 (1.46)	-27.24 (1.84)	-110.27 (1.59)	-9.59 (1.97)
9	1	-4.37 (5.30)	30.93 (1.02)	34.84 (6.21)	-7.84 (1.72)	-15.03 (1.34)	-92.93 (1.38)	-6.01 (1.20)
	2	-11.13 (2.68)	29.55 (2.59)	39.56 (3.53)	-10.13 (1.72)	-18.10 (2.27)	-92.21 (2.70)	-7.21 (3.20)
	3	-12.68 (2.04)	42.34 (35.44)	54.62 (34.46)	-15.34 (3.26)	-23.45 (6.24)	-109.32 (31.17)	-5.39 (5.77)
	4	-8.94 (2.25)	33.13 (1.55)	41.62 (2.56)	-10.25 (1.19)	-17.98 (2.51)	-93.14 (0.34)	-6.34 (1.48)
	5	-15.21 (3.27)	31.56 (0.99)	46.94 (4.28)	-4.63 (1.32)	-13.13 (1.21)	-89.68 (0.66)	-10.63 (2.99)
	6	-9.47 (1.52)	29.80 (1.21)	38.10 (2.32)	-11.67 (1.32)	-19.52 (1.66)	-94.73 (1.41)	-5.54 (3.11)
10	1	-21.32 (3.90)	25.90 (1.94)	47.23 (3.25)	0.77 (0.80)	-4.07 (1.50)	-92.74 (1.60)	-4.26 (1.25)
	2	-25.56 (3.04)	25.56 (2.45)	51.12 (4.24)	-2.27 (2.21)	-3.60 (3.34)	-95.71 (2.87)	-4.84 (2.24)
	3	-21.53 (1.52)	26.07 (1.74)	47.60 (2.55)	-5.31 (3.15)	-10.87 (3.56)	-98.20 (1.86)	-6.17 (2.29)
	4	-20.59 (2.31)	28.38 (2.68)	48.96 (1.84)	-0.76 (1.45)	-5.12 (1.06)	-94.60 (2.10)	-4.43 (0.92)
	5	-21.98 (2.72)	27.0 (1.95)	48.98 (2.77)	-3.19 (3.18)	-5.59 (2.49)	-96.97 (1.29)	-4.95 (0.80)
	6	-23.53 (2.83)	26.92 (2.22)	50.58 (2.48)	-1.81 (2.99)	-5.09 (1.33)	-96.37 (3.06)	-5.11 (2.56)

Continued.

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
11	1	-21.89 (1.67)	29.73 (1.75)	49.72 (4.62)	-0.48 (1.33)	-2.92 (1.27)	-89.59 (0.56)	-3.08 (1.44)
	2	-24.79 (1.51)	31.43 (1.27)	53.84 (3.76)	-0.76 (1.49)	0.42 (2.33)	-90.77 (1.13)	-2.15 (2.69)
	3	-20.67 (3.39)	30.96 (1.06)	51.40 (3.29)	-2.45 (1.10)	-1.47 (2.01)	-93.37 (2.02)	-3.55 (2.50)
	4	-21.04 (2.77)	32.72 (2.65)	53.77 (4.02)	-3.19 (0.98)	-7.98 (1.86)	-93.39 (1.31)	-2.61 (1.80)
	5	-27.30 (1.26)	30.25 (1.01)	56.18 (1.73)	-2.66 (1.07)	-2.60 (0.93)	-91.59 (1.08)	-4.50 (1.12)
	6	-23.92 (2.53)	32.16 (1.07)	52.22 (3.64)	-2.39 (3.07)	-3.23 (2.91)	-94.72 (4.28)	-2.26 (3.91)
16	1	-19.24 (1.76)	25.19 (2.51)	43.40 (2.55)	-10.16 (1.23)	-14.18 (3.70)	-106.84 (1.35)	-5.91 (2.93)
	2	-23.16 (2.38)	30.13 (2.99)	51.90 (6.89)	-7.51 (0.56)	-15.63 (1.91)	-103.48 (1.06)	-5.03 (3.47)
	3	-21.68 (1.73)	31.60 (1.0)	51.87 (3.79)	-6.67 (2.14)	-13.37 (3.18)	-102.81 (1.06)	-5.07 (2.27)
	4	-14.50 (9.44)	26.31 (1.86)	40.81 (9.98)	-3.93 (3.11)	-13.27 (5.05)	-99.53 (1.26)	-7.49 (3.67)
	5	-18.61 (2.59)	29.21 (2.52)	47.81 (1.76)	-3.15 (1.79)	-11.79 (2.22)	-99.60 (1.52)	-6.09 (1.96)
	6	-23.41 (3.61)	28.03 (3.35)	51.34 (5.89)	-8.65 (1.27)	-13.21 (4.42)	-106.10 (2.92)	-4.56 (3.63)
20	1	-27.30 (2.28)	21.42 (1.65)	43.96 (8.32)	-6.85 (1.88)	-11.67 (5.63)	-104.78 (1.74)	-13.63 (2.53)
	2	-32.91 (3.04)	23.44 (1.74)	50.15 (6.33)	-8.50 (1.89)	-11.27 (5.30)	-106.03 (1.82)	-14.65 (4.38)
	3	-26.65 (2.55)	24.39 (1.34)	45.98 (4.94)	-10.29 (0.82)	-15.78 (1.63)	-108.65 (1.43)	-14.22 (3.70)
	4	-30.24 (2.12)	17.51 (1.71)	44.34 (6.31)	-4.19 (1.97)	-10.21 (1.93)	-100.65 (0.93)	-11.07 (1.88)
	5	-33.10 (1.68)	17.87 (2.18)	44.05 (6.49)	-6.81 (0.93)	-7.48 (1.53)	-102.55 (1.51)	-11.16 (3.79)
	6	-28.79 (2.97)	22.81 (1.07)	50.04 (6.06)	-8.18 (1.51)	-13.48 (4.22)	-103.96 (3.20)	-12.88 (3.98)

Continued.

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
21	1	-14.80 (3.31)	39.82 (0.94)	54.63 (4.17)	-6.67 (0.90)	-10.22 (2.20)	-98.85 (1.76)	-5.50 (1.54)
	2	-15.46 (1.75)	37.77 (2.76)	53.23 (2.25)	-3.53 (2.82)	-6.92 (2.48)	-97.89 (0.74)	-4.61 (4.06)
	3	-16.95 (2.50)	38.77 (2.41)	54.0 (5.45)	-5.91 (3.24)	-7.77 (3.46)	-97.95 (2.19)	-5.44 (4.55)
	4	-17.59 (3.02)	28.89 (2.43)	46.48 (3.93)	-2.01 (2.22)	-5.33 (8.90)	-97.66 (1.33)	-9.56 (1.09)
	5	-15.99 (3.65)	32.99 (4.58)	48.99 (3.31)	-3.66 (2.08)	-8.38 (2.07)	-97.99 (0.22)	-5.71 (1.97)
	6	-17.27 (1.98)	34.50 (4.98)	51.77 (5.96)	-3.09 (2.13)	-7.07 (3.38)	-98.34 (2.29)	-6.07 (3.36)
22	1	-21.45 (1.05)	24.61 (2.17)	46.06 (3.07)	-9.83 (2.65)	-17.30 (4.79)	-110.68 (2.55)	-8.28 (2.57)
	2	-24.37 (1.95)	30.83 (3.85)	55.20 (5.05)	-7.39 (3.14)	-18.23 (3.94)	-107.79 (1.54)	-7.98 (2.17)
	3	-17.71 (3.92)	33.38 (1.62)	48.39 (4.05)	-8.11 (1.28)	-17.38 (3.29)	-108.43 (2.37)	-10.0 (3.41)
	4	-13.16 (2.36)	24.51 (1.69)	33.28 (6.23)	-11.04 (2.79)	-21.49 (4.03)	-110.76 (1.61)	-7.33 (3.66)
	5	-18.16 (2.56)	30.41 (2.95)	48.57 (3.44)	-7.56 (1.80)	-18.75 (1.30)	-108.88 (1.65)	-6.46 (2.35)
	6	-22.40 (1.35)	29.71 (4.51)	52.11 (4.87)	-6.41 (2.41)	-15.55 (4.48)	-107.18 (1.95)	-10.11 (1.72)
25	1	-17.76 (3.17)	29.01 (1.03)	46.78 (3.32)	-2.77 (1.32)	-13.36 (0.81)	-102.42 (1.02)	-15.51 (1.52)
	2	-17.12 (1.80)	32.23 (0.98)	49.04 (1.70)	-1.74 (1.12)	-11.96 (2.16)	-101.15 (0.75)	-15.79 (1.01)
	3	-19.25 (2.06)	30.74 (1.01)	48.12 (4.85)	-4.23 (1.61)	-15.51 (3.52)	-106.52 (1.71)	-16.60 (2.77)
	4	-10.71 (2.75)	26.96 (2.81)	36.84 (2.68)	-3.48 (2.08)	-13.57 (2.31)	-102.97 (0.93)	-12.54 (1.50)
	5	-4.96 (5.37)	30.05 (1.57)	35.01 (4.22)	-0.09 (1.03)	-9.77 (1.51)	-100.10 (0.78)	-11.67 (1.19)
	6	-18.67 (4.08)	32.52 (3.97)	51.19 (3.68)	-2.61 (1.45)	-12.79 (2.41)	-102.55 (0.87)	-15.11 (1.62)

Continued.

Subj	Cond	Cont	DF	DF ROM	Abduction	Abduction ROM	External Rotation	External Rotation ROM
26	1	-13.39 (4.82)	28.54 (1.73)	41.93 (6.06)	-2.12 (1.67)	-9.25 (3.69)	-101.47 (1.62)	-8.53 (2.07)
	2	-16.10 (3.12)	31.24 (1.66)	47.34 (2.60)	-2.58 (0.99)	-10.16 (2.87)	-104.29 (1.32)	-8.70 (1.0)
	3	-15.49 (3.98)	28.50 (3.69)	43.98 (6.06)	-5.06 (1.53)	-10.45 (1.48)	-103.57 (1.49)	-8.20 (1.48)
	4	-21.68 (1.42)	28.27 (3.54)	49.95 (4.70)	-4.75 (0.79)	-11.71 (1.31)	-105.87 (1.23)	-9.81 (0.85)
	5	-16.39 (2.25)	31.43 (2.02)	47.81 (2.32)	-4.91 (1.75)	-9.70 (2.48)	-105.32 (1.93)	-7.61 (1.58)
	6	-17.10 (1.33)	29.01 (2.34)	46.11 (3.40)	-1.94 (0.56)	-10.36 (1.75)	-103.51 (1.18)	-10.63 (0.91)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AK

Female Subject Table Right Ankle Angular Velocity

Female subject ankle angular data.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
1	1	541.71 (56.36)	748.45 (39.19)	-237.81 (24.86)	-111.03 (37.25)
	2	607.85 (44.46)	868.84 (29.33)	-268.63 (88.04)	-82.26 (25.60)
	3	662.82 (36.14)	876.45 (43.97)	-216.06 (64.72)	-69.38 (56.25)
	4	459.33 (48.55)	738.56 (23.23)	-201.63 (29.28)	-89.56 (24.41)
	5	607.22 (27.82)	857.36 (16.75)	-204.78 (8.67)	-141.13 (23.81)
	6	619.55 (86.26)	895.12 (76.57)	-271.44 (77.23)	-144.87 (30.33)
2	1	490.85 (85.25)	906.29 (25.79)	-251.30 (30.20)	-173.06 (42.64)
	2	625.01 (99.84)	955.85 (81.08)	-226.16 (59.96)	-126.87 (47.82)
	3	665.69 (83.40)	1011.73 (81.81)	-325.93 (43.15)	-190.31 (39.49)
	4	317.97 (63.99)	715.74 (52.90)	-206.93 (32.94)	-96.75 (35.10)
	5	353.44 (31.06)	737.39 (76.20)	-212.93 (62.98)	-104.38 (39.73)
	6	518.25 (93.75)	844.57 (27.15)	-289.53 (69.03)	-146.69 (52.21)
3	1	395.39 (37.32)	717.57 (90.76)	-246.47 (37.92)	-133.42 (22.02)
	2	472.27 (18.47)	737.09 (30.78)	-240.24 (59.50)	-113.27 (13.68)
	3	432.06 (112.51)	713.64 (69.73)	-332.29 (45.60)	-156.53 (52.96)
	4	288.46 (52.88)	622.69 (30.96)	-193.43 (18.82)	-96.53 (19.52)
	5	347.05 (57.72)	683.32 (37.74)	-202.86 (45.75)	-119.17 (35.68)
	6	478.17 (88.08)	759.92 (51.27)	-282.34 (34.53)	-100.95 (41.94)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
4	1	470.68	805.42	-255.65	-121.55
		(72.57)	(9.61)	(15.36)	(72.82)
	2	567.92	846.04	-285.99	-160.03
		(61.55)	(54.32)	(54.64)	(32.96)
	3	656.92	923.81	-293.69	-154.72
		(150.96)	(54.02)	(14.64)	(74.71)
	4	351.01	520.60	-305.26	-152.41
		(28.34)	(56.39)	(29.31)	(11.45)
	5	515.74	791.10	-277.06	-113.11
		(70.01)	(34.75)	(39.17)	(45.51)
	6	537.88	887.43	-340.73	-174.43
		(63.56)	(35.10)	(15.58)	(14.32)
6	1	558.25	761.72	-37.16	-67.40
		(39.89)	(45.38)	(7.54)	(10.13)
	2	490.57	787.22	-59.58	-63.37
		(23.16)	(63.17)	(15.01)	(25.59)
	3	521.21	688.84	-50.72	-63.95
		(113.68)	(38.43)	(32.60)	(16.02)
	4	330.06	515.32	-56.06	-72.07
		(85.11)	(35.73)	(15.87)	(11.48)
	5	348.15	670.89	-34.42	-70.46
		(63.96)	(33.91)	(10.04)	(22.40)
	6	397.94	746.16	-45.31	-74.07
		(63.76)	(41.17)	(7.45)	(11.92)
7	1	549.40	746.01	-275.09	-49.10
		(86.33)	(67.18)	(55.27)	(18.04)
	2	598.22	833.90	-216.10	-24.37
		(48.76)	(68.25)	(16.88)	(8.46)
	3	567.68	839.19	-235.96	-138.67
		(117.16)	(65.54)	(99.70)	(161.11)
	4	385.65	555.31	-197.86	-28.39
		(46.67)	(148.99)	(36.44)	(8.30)
	5	611.18	810.13	-240.84	-32.60
		(88.15)	(70.29)	(25.93)	(7.84)
	6	573.28	919.95	-255.79	-81.84
		(114.42)	(102.74)	(46.14)	(48.94)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
8	1	624.48 (81.37)	943.14 (73.87)	-319.61 (75.17)	-83.09 (24.90)
	2	546.28 (281.93)	1074.03 (201.70)	-372.01 (63.06)	-149.17 (113.89)
	3	705.18 (97.84)	1002.41 (36.10)	-418.96 (85.88)	-133.73 (39.42)
	4	589.33 (51.45)	875.82 (64.12)	-324.31 (68.28)	-83.46 (14.66)
	5	571.38 (44.77)	938.69 (40.70)	-413.68 (101.24)	-81.31 (17.56)
	6	741.29 (96.81)	1051.15 (72.73)	-364.60 (71.38)	-131.97 (30.27)
9	1	440.37 (64.19)	544.81 (106.81)	-231.33 (44.19)	-131.51 (33.79)
	2	547.92 (68.90)	682.09 (52.53)	-302.89 (63.57)	-162.69 (85.39)
	3	632.17 (277.31)	1435.77 (1591.96)	-515.07 (496.89)	-864.07 (1530.31)
	4	463.63 (119.05)	648.26 (49.73)	-263.35 (45.81)	-166.02 (75.97)
	5	539.60 (171.47)	794.29 (51.75)	-261.18 (59.89)	-187.69 (121.89)
	6	652.70 (120.81)	742.55 (108.63)	-300.54 (62.57)	-139.78 (36.75)
10	1	372.75 (107.95)	698.27 (34.47)	-180.34 (39.65)	-43.01 (15.20)
	2	397.94 (110.10)	896.67 (96.37)	-209.23 (108.96)	-96.91 (30.53)
	3	449.11 (82.63)	848.0 (50.49)	-397.94 (57.25)	-82.87 (10.81)
	4	351.23 (59.32)	724.84 (74.98)	-184.68 (12.87)	-53.14 (17.68)
	5	451.84 (45.21)	811.11 (65.17)	-211.58 (76.15)	-81.03 (20.52)
	6	455.03 (106.07)	883.51 (82.09)	-268.36 (53.07)	-76.13 (15.94)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
11	1	455.08 (41.68)	796.07 (36.66)	-197.20 (32.64)	-29.68 (15.69)
	2	603.38 (54.74)	1029.46 (47.19)	-264.96 (36.77)	-29.48 (8.04)
	3	753.31 (73.03)	1087.61 (42.26)	-219.45 (20.51)	-42.35 (10.49)
	4	389.62 (38.11)	723.84 (25.22)	-191.84 (41.98)	-21.26 (9.83)
	5	432.90 (41.06)	900.35 (54.86)	-247.36 (70.37)	-28.08 (9.31)
	6	634.19 (124.46)	1074.39 (46.66)	-277.87 (60.23)	-95.15 (107.51)
16	1	434.10 (46.52)	808.31 (35.17)	-156.90 (62.83)	-115.74 (20.51)
	2	551.12 (209.86)	868.70 (130.83)	-283.37 (34.57)	-176.96 (90.32)
	3	631.70 (74.28)	959.34 (26.54)	-251.31 (63.82)	-78.26 (28.57)
	4	242.55 (80.89)	608.24 (109.39)	-268.96 (70.39)	-86.29 (36.11)
	5	489.84 (82.65)	784.32 (29.88)	-211.87 (46.31)	-79.12 (27.29)
	6	400.72 (170.06)	872.13 (63.86)	-249.80 (45.19)	-148.54 (66.69)
20	1	524.61 (37.48)	878.15 (42.81)	-248.87 (39.53)	-122.04 (20.47)
	2	523.09 (93.30)	1089.71 (52.05)	-227.85 (48.45)	-160.67 (32.61)
	3	762.98 (84.39)	1125.26 (62.84)	-281.08 (50.85)	-170.71 (24.16)
	4	249.05 (37.37)	652.88 (30.40)	-230.84 (24.48)	-117.93 (13.81)
	5	350.09 (75.68)	809.19 (21.06)	-220.42 (33.78)	-126.18 (28.91)
	6	549.15 (37.23)	984.38 (60.39)	-259.41 (51.63)	-119.38 (19.52)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
21	1	543.51 (82.56)	854.78 (32.88)	-178.01 (77.89)	-135.32 (39.07)
	2	642.69 (39.86)	885.62 (61.08)	-229.69 (121.15)	-72.42 (47.38)
	3	708.42 (48.02)	972.56 (28.19)	-181.45 (130.70)	-112.65 (41.38)
	4	420.13 (67.19)	762.62 (48.37)	-161.15 (106.12)	-112.73 (47.62)
	5	387.07 (80.61)	768.91 (25.29)	-149.0 (59.16)	-83.52 (16.53)
	6	557.12 (38.44)	853.41 (55.26)	-208.92 (56.39)	-116.04 (49.35)
22	1	425.37 (78.60)	828.39 (42.72)	-264.05 (51.19)	-91.59 (38.06)
	2	599.22 (36.18)	1074.70 (113.96)	-244.62 (86.18)	-87.98 (18.33)
	3	825.03 (151.68)	1145.13 (61.78)	-218.01 (43.03)	-127.17 (57.30)
	4	278.68 (62.69)	643.15 (32.40)	-275.03 (69.32)	-89.10 (22.83)
	5	488.44 (104.94)	880.40 (34.16)	-213.21 (46.84)	-100.31 (33.26)
	6	563.45 (49.83)	953.36 (67.45)	-281.94 (80.47)	-80.42 (20.23)
25	1	435.89 (57.37)	734.49 (15.02)	-286.80 (39.57)	-156.08 (11.47)
	2	508.68 (40.67)	811.05 (41.58)	-315.07 (47.86)	-161.52 (18.48)
	3	528.01 (80.82)	920.51 (40.33)	-373.43 (31.01)	-144.53 (62.97)
	4	334.63 (34.34)	590.59 (13.19)	-217.50 (27.79)	-110.73 (21.53)
	5	312.64 (71.71)	579.93 (66.92)	-170.12 (35.90)	-95.75 (7.97)
	6	392.48 (89.91)	745.25 (56.38)	-272.50 (16.56)	-146.97 (22.30)

Continued.

Subject	Condition	Contact	Dorsiflexion	Abduction	External Rotation
26	1	520.01 (64.77)	781.18 (62.56)	-173.28 (69.34)	-102.66 (18.33)
	2	614.93 (149.15)	916.98 (51.79)	-165.92 (65.82)	-97.33 (42.14)
	3	600.87 (76.80)	905.45 (150.89)	-215.66 (80.0)	-135.26 (82.10)
	4	451.68 (71.08)	825.53 (17.96)	-224.33 (32.35)	-131.30 (29.92)
	5	437.63 (44.44)	811.37 (33.34)	-222.42 (67.30)	-87.87 (23.18)
	6	618.04 (71.06)	910.06 (61.66)	-183.08 (21.14)	-114.0 (19.40)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AL

Female Subject Table Right Knee Angle

Female subject knee angle data.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
1	1	-28.49 (2.39)	-97.01 (4.30)	-69.0 (2.87)	17.07 (0.84)	8.44 (2.09)	21.06 (1.80)	27.38 (1.56)
	2	-32.42 (3.09)	-115.20 (1.82)	-83.17 (3.64)	15.50 (0.48)	5.74 (1.30)	22.33 (1.84)	29.46 (1.40)
	3	-33.53 (1.32)	-121.46 (4.22)	-87.93 (4.40)	14.32 (2.06)	5.35 (1.96)	27.11 (2.33)	30.04 (2.16)
	4	-25.53 (3.09)	-91.16 (7.02)	-66.70 (3.29)	15.94 (1.25)	9.14 (1.96)	19.80 (2.17)	26.17 (1.81)
	5	-23.54 (1.21)	-103.89 (2.44)	-80.35 (2.64)	11.50 (1.03)	7.36 (1.83)	20.28 (1.10)	24.53 (0.82)
	6	-33.67 (2.58)	-121.30 (3.85)	-87.19 (2.72)	16.16 (0.99)	4.53 (1.14)	27.36 (3.15)	31.12 (2.23)
2	1	-20.77 (3.22)	-71.71 (4.36)	-50.93 (1.56)	13.62 (1.65)	10.01 (4.01)	8.52 (1.29)	15.29 (3.54)
	2	-25.07 (2.55)	-91.28 (2.68)	-66.21 (3.99)	13.75 (0.72)	9.97 (1.43)	15.27 (0.95)	20.76 (2.50)
	3	-26.81 (1.37)	-101.81 (5.24)	-74.99 (5.63)	16.01 (1.15)	13.16 (1.57)	17.62 (1.57)	23.43 (1.21)
	4	-18.39 (4.95)	-60.73 (4.94)	-37.91 (9.71)	8.08 (1.48)	8.26 (1.45)	7.28 (1.56)	10.36 (4.88)
	5	-22.91 (1.82)	-69.49 (3.56)	-46.58 (4.83)	12.16 (2.22)	9.18 (3.32)	9.77 (1.04)	12.98 (3.06)
	6	-19.0 (2.06)	-68.22 (4.56)	-49.22 (5.18)	10.95 (1.51)	8.51 (2.0)	7.46 (1.84)	14.34 (5.90)
3	1	-27.17 (2.62)	-85.72 (3.02)	-56.59 (7.33)	7.74 (0.65)	5.68 (1.51)	14.92 (0.68)	12.12 (1.24)
	2	-31.66 (1.73)	-100.77 (3.80)	-69.10 (3.73)	16.85 (1.62)	9.59 (2.22)	18.92 (2.86)	22.33 (2.66)
	3	-30.52 (0.75)	-102.69 (3.07)	-72.17 (3.50)	15.23 (0.99)	9.82 (0.78)	20.47 (1.34)	20.37 (1.70)
	4	-22.47 (1.11)	-76.51 (3.03)	-54.04 (2.53)	4.81 (0.97)	4.28 (1.65)	12.40 (0.72)	11.07 (1.30)
	5	-26.70 (0.77)	-88.98 (3.94)	-61.31 (5.44)	12.01 (1.04)	9.86 (1.59)	16.39 (1.76)	15.14 (1.91)
	6	-28.83 (2.35)	-92.30 (4.69)	-63.47 (4.24)	13.72 (0.65)	10.25 (1.24)	14.98 (1.76)	14.95 (2.21)

Continued.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
4	1	-25.63	-88.75	-63.12	7.83	3.48	6.40	13.39
		(1.04)	(7.16)	(6.71)	(2.20)	(1.81)	(1.01)	(1.22)
	2	-24.74	-99.56	-74.89	8.58	2.77	8.41	16.12
		(3.19)	(9.04)	(6.45)	(1.24)	(1.70)	(1.40)	(1.32)
	3	-28.17	-106.83	-78.66	10.67	4.55	10.05	18.76
		(2.91)	(5.51)	(3.28)	(1.46)	(1.67)	(3.05)	(3.16)
	4	-30.46	-88.33	-57.88	7.03	1.26	7.06	15.03
		(2.06)	(3.19)	(4.07)	(0.68)	(0.43)	(0.71)	(1.11)
	5	-27.12	-100.31	-73.18	8.16	3.05	8.47	15.71
		(3.48)	(3.86)	(3.97)	(0.84)	(1.37)	(1.36)	(2.04)
	6	-26.03	-95.31	-70.63	8.57	1.52	8.22	16.68
		(1.51)	(6.42)	(4.07)	(0.67)	(0.79)	(0.69)	(1.01)
6	1	-24.04	-69.95	-45.92	3.20	6.84	3.72	1.33
		(1.12)	(6.94)	(6.08)	(1.47)	(1.48)	(1.16)	(1.78)
	2	-25.76	-71.57	-24.37	-2.07	1.68	3.25	2.66
		(1.81)	(9.91)	(27.75)	(0.86)	(0.65)	(2.04)	(1.51)
	3	-27.04	-83.59	-56.55	7.52	9.26	5.28	4.54
		(0.79)	(5.62)	(5.91)	(1.14)	(2.60)	(1.06)	(1.13)
	4	-17.20	-48.22	-27.09	0.40	2.02	8.20	3.69
		(1.75)	(2.25)	(9.06)	(0.43)	(1.38)	(0.60)	(1.94)
	5	-20.98	-52.30	-23.70	-2.46	0.74	4.09	3.68
		(1.32)	(1.66)	(10.22)	(0.78)	(0.59)	(1.36)	(2.44)
	6	-22.25	-59.94	-31.59	-0.45	2.42	4.49	1.17
		(1.36)	(5.38)	(16.85)	(0.67)	(1.59)	(0.81)	(3.01)
7	1	-28.89	-100.62	-71.73	15.61	6.14	10.26	14.71
		(2.67)	(1.68)	(1.50)	(1.44)	(2.08)	(2.07)	(3.39)
	2	-27.73	-111.35	-83.61	13.65	6.76	14.65	14.52
		(2.84)	(2.94)	(3.75)	(1.88)	(1.23)	(0.99)	(1.93)
	3	-27.06	-107.15	-80.09	16.63	9.56	13.30	14.29
		(1.04)	(4.67)	(3.74)	(1.64)	(1.22)	(2.17)	(3.42)
	4	-33.06	-99.54	-66.48	14.27	4.76	11.14	13.75
		(4.59)	(5.47)	(5.07)	(0.81)	(2.05)	(1.29)	(2.79)
	5	-26.45	-101.19	-74.74	15.40	8.53	12.69	16.33
		(1.27)	(3.77)	(3.42)	(0.63)	(0.57)	(1.91)	(2.39)
	6	-26.46	-104.52	-78.06	14.96	7.60	12.25	14.18
		(1.28)	(5.62)	(4.49)	(0.76)	(0.39)	(1.91)	(2.94)

Continued.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
8	1	-19.93	-95.93	-76.0	18.94	11.26	25.62	30.05
		(2.23)	(3.19)	(4.05)	(2.68)	(1.99)	(1.38)	(2.44)
	2	-21.01	-98.69	-77.68	22.66	15.51	24.85	29.97
		(2.12)	(4.30)	(4.67)	(2.0)	(1.82)	(1.52)	(3.60)
	3	-22.52	-104.46	-81.94	24.58	15.62	28.69	30.99
		(3.53)	(1.55)	(2.75)	(1.79)	(2.48)	(3.02)	(2.70)
	4	-20.68	-94.38	-73.98	17.74	10.09	23.98	28.01
		(2.69)	(2.23)	(3.83)	(0.88)	(1.20)	(1.82)	(2.03)
	5	-21.12	-102.60	-82.01	23.42	16.51	25.65	32.27
		(2.09)	(4.09)	(3.06)	(0.91)	(1.16)	(2.30)	(2.42)
	6	-22.02	-103.76	-81.74	24.53	14.99	29.84	32.68
		(1.49)	(2.36)	(1.41)	(0.76)	(1.16)	(1.46)	(1.49)
9	1	-28.86	-129.04	-100.18	12.07	2.83	27.01	31.64
		(4.77)	(1.52)	(4.84)	(1.39)	(1.45)	(0.88)	(1.96)
	2	-26.18	-131.24	-105.06	12.96	4.50	29.27	34.64
		(3.99)	(1.33)	(4.44)	(1.86)	(1.91)	(1.90)	(3.19)
	3	-33.14	-135.74	-102.60	15.11	3.15	36.11	35.29
		(2.66)	(4.46)	(6.20)	(0.62)	(0.84)	(2.77)	(3.53)
	4	-30.79	-132.77	-101.98	12.25	2.25	28.71	31.85
		(2.03)	(3.41)	(3.70)	(1.68)	(1.54)	(1.85)	(2.37)
	5	-30.20	-121.96	-91.77	9.70	3.47	20.31	26.42
		(1.77)	(3.59)	(3.17)	(0.47)	(0.87)	(1.57)	(2.05)
	6	-32.66	-132.33	-99.67	13.51	2.66	31.29	30.77
		(2.37)	(2.79)	(4.02)	(1.01)	(1.10)	(1.34)	(2.17)
10	1	-31.41	-87.45	-56.04	2.51	0.91	-5.22	2.25
		(2.07)	(3.40)	(2.45)	(0.49)	(0.77)	(0.54)	(0.76)
	2	-40.72	-105.76	-65.04	8.51	2.84	-1.23	8.02
		(6.35)	(6.23)	(1.76)	(1.20)	(1.54)	(1.07)	(1.40)
	3	-41.59	-120.78	-79.18	12.54	5.75	3.36	14.30
		(2.68)	(4.22)	(5.47)	(1.31)	(1.14)	(3.16)	(3.15)
	4	-40.42	-94.16	-53.74	5.21	1.46	-4.23	3.63
		(2.85)	(2.29)	(1.16)	(1.10)	(0.36)	(1.49)	(1.78)
	5	-40.50	-103.83	-63.33	7.52	2.95	-2.44	6.01
		(3.33)	(1.51)	(4.76)	(1.52)	(0.95)	(1.39)	(1.50)
	6	-41.34	-110.23	-68.89	9.89	4.55	-1.21	7.32
		(2.76)	(4.48)	(4.76)	(1.61)	(1.43)	(1.75)	(1.89)

Continued.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
11	1	-20.64	-68.18	-47.54	3.97	0.65	-2.95	5.53
		(1.24)	(5.92)	(6.25)	(0.72)	(1.54)	(1.53)	(1.68)
	2	-25.38	-88.42	-63.04	4.65	-1.43	0.68	6.42
		(1.42)	(3.65)	(4.69)	(1.03)	(0.89)	(0.87)	(4.06)
	3	-26.63	-98.42	-71.79	2.16	-2.45	3.68	6.88
		(1.52)	(6.40)	(6.24)	(0.95)	(2.76)	(1.72)	(2.28)
	4	-20.78	-72.42	-51.64	4.60	1.26	-0.58	6.10
		(3.21)	(3.91)	(2.82)	(1.21)	(0.89)	(1.06)	(1.94)
	5	-25.21	-87.43	-62.21	5.30	-0.15	-0.77	9.85
		(1.69)	(3.96)	(3.26)	(0.88)	(1.36)	(1.22)	(1.88)
	6	-26.67	-92.47	-65.79	4.73	-1.62	2.48	9.04
		(0.97)	(2.96)	(3.29)	(1.61)	(1.59)	(1.22)	(1.11)
16	1	-23.99	-79.83	-51.16	11.40	8.71	1.49	6.69
		(2.56)	(5.69)	(12.52)	(2.73)	(3.45)	(1.36)	(2.98)
	2	-25.67	-89.83	-63.97	7.35	4.73	3.36	5.83
		(2.08)	(4.56)	(4.83)	(1.87)	(1.28)	(0.61)	(2.25)
	3	-28.17	-100.51	-72.34	8.40	4.55	5.44	6.52
		(1.63)	(4.39)	(5.51)	(1.74)	(1.62)	(1.09)	(1.65)
	4	-30.02	-68.96	-38.94	9.87	3.58	0.86	10.36
		(8.21)	(6.81)	(2.90)	(2.09)	(3.65)	(2.46)	(3.10)
	5	-23.53	-76.51	-52.98	4.31	4.88	-1.61	4.43
		(1.70)	(4.0)	(2.42)	(1.62)	(1.49)	(0.77)	(0.78)
	6	-24.91	-79.44	-54.0	9.71	6.77	0.50	8.31
		(2.12)	(7.03)	(7.97)	(0.95)	(1.45)	(1.15)	(1.40)
20	1	-16.93	-53.92	-23.28	6.47	2.0	6.08	7.71
		(0.90)	(2.44)	(18.66)	(1.23)	(2.83)	(1.21)	(2.39)
	2	-18.55	-67.23	-48.68	8.40	0.91	9.35	9.56
		(0.66)	(5.44)	(5.67)	(1.40)	(3.0)	(0.69)	(6.0)
	3	-22.34	-77.47	-55.14	11.58	5.08	9.88	11.80
		(1.23)	(1.41)	(0.92)	(1.17)	(2.99)	(1.40)	(4.96)
	4	-10.84	-39.55	-25.73	7.84	3.99	0.60	9.61
		(1.23)	(2.76)	(9.27)	(0.95)	(2.13)	(2.30)	(1.40)
	5	-11.53	-45.94	-29.23	6.78	4.96	4.86	10.46
		(1.65)	(2.96)	(11.70)	(1.17)	(2.42)	(0.65)	(3.79)
	6	-18.18	-60.77	-35.53	6.44	1.16	8.22	6.13
		(1.87)	(3.87)	(14.71)	(1.12)	(2.07)	(0.72)	(1.50)

Continued.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
21	1	-20.51 (3.72)	-95.02 (2.59)	-74.51 (3.43)	1.33 (1.59)	3.83 (1.72)	11.55 (1.22)	12.96 (1.85)
	2	-23.99 (2.57)	-102.72 (5.32)	-78.73 (5.68)	0.62 (1.20)	1.97 (1.27)	13.18 (0.80)	9.39 (2.55)
	3	-21.89 (2.59)	-108.43 (7.42)	-86.53 (5.88)	3.83 (2.13)	4.93 (2.48)	14.59 (0.90)	10.56 (4.12)
	4	-16.80 (3.76)	-64.59 (6.37)	-47.79 (5.66)	-1.31 (1.79)	2.42 (1.12)	18.29 (1.37)	9.03 (3.31)
	5	-19.15 (3.72)	-74.41 (9.56)	-55.26 (6.70)	-0.28 (1.58)	0.87 (3.68)	14.91 (2.18)	9.87 (4.83)
	6	-18.75 (1.10)	-88.26 (6.97)	-69.51 (6.80)	0.06 (2.16)	1.09 (1.86)	15.52 (1.19)	13.23 (3.29)
22	1	-16.07 (1.04)	-63.23 (4.53)	-47.16 (4.19)	7.96 (1.56)	4.38 (1.28)	6.04 (1.07)	7.08 (2.71)
	2	-19.80 (1.63)	-79.66 (5.72)	-59.86 (4.64)	9.58 (1.73)	4.53 (2.09)	8.85 (1.80)	9.09 (2.38)
	3	-26.08 (3.21)	-103.20 (8.0)	-77.12 (9.08)	12.02 (1.95)	5.84 (1.27)	17.78 (1.98)	21.22 (2.94)
	4	-21.75 (4.24)	-60.76 (2.66)	-39.01 (1.80)	9.41 (1.28)	6.32 (0.81)	4.53 (1.22)	6.67 (3.04)
	5	-19.77 (3.43)	-73.54 (3.54)	-53.77 (3.16)	10.96 (3.39)	6.04 (3.38)	7.27 (0.99)	9.30 (3.88)
	6	-17.56 (1.50)	-67.52 (3.95)	-49.96 (2.99)	7.30 (1.40)	3.29 (2.72)	6.84 (0.92)	6.26 (3.79)
25	1	-27.54 (2.17)	-85.50 (4.19)	-57.96 (3.52)	3.59 (0.93)	0.61 (0.40)	13.64 (0.96)	9.86 (1.55)
	2	-34.16 (1.48)	-105.27 (1.93)	-71.11 (0.82)	4.58 (0.77)	-0.59 (1.68)	14.89 (1.48)	13.84 (0.97)
	3	-37.17 (3.11)	-111.94 (5.63)	-74.77 (3.52)	0.73 (2.30)	-4.74 (3.05)	14.59 (0.97)	9.05 (2.73)
	4	-25.75 (3.61)	-81.27 (4.12)	-55.51 (5.44)	5.65 (1.14)	1.17 (1.07)	11.68 (0.44)	12.62 (2.46)
	5	-32.90 (5.26)	-87.16 (7.06)	-54.26 (6.42)	3.12 (1.27)	-2.86 (2.42)	10.77 (1.26)	11.49 (1.05)
	6	-32.07 (3.15)	-99.46 (5.20)	-67.39 (4.63)	3.76 (1.58)	-1.34 (2.05)	15.73 (1.81)	12.80 (2.69)

Continued.

Subj	Cond	Cont	Extension	Flexion ROM	Adduction	Adduction ROM	Internal Rotation	Internal Rotation ROM
26	1	-21.13	-71.36	-50.23	11.61	4.17	5.90	14.65
		(1.53)	(4.03)	(3.01)	(1.02)	(1.31)	(1.14)	(1.51)
	2	-23.49	-80.97	-57.47	11.20	3.35	5.88	12.46
		(3.04)	(5.68)	(4.42)	(1.90)	(2.52)	(1.91)	(1.91)
	3	-29.66	-94.76	-65.10	15.23	4.74	13.43	16.43
		(3.42)	(5.08)	(4.75)	(2.30)	(2.73)	(1.66)	(2.67)
	4	-14.84	-67.96	-53.12	12.59	4.33	7.35	17.63
		(1.63)	(3.41)	(2.51)	(0.65)	(0.73)	(1.55)	(1.35)
	5	-23.33	-81.93	-58.61	11.46	1.78	8.57	14.76
		(1.84)	(4.33)	(4.62)	(0.74)	(0.98)	(1.59)	(1.69)
	6	-23.67	-81.92	-58.25	12.34	4.18	7.72	15.79
		(2.05)	(4.17)	(5.11)	(1.24)	(1.46)	(1.15)	(1.69)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AM

Female Subject Table Right Knee Angular Velocity

Female subject knee angular velocity data.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
1	1	-435.27	-595.08	168.46	119.93
		(15.42)	(19.66)	(26.54)	(14.50)
	2	-446.81	-646.72	180.61	131.57
		(23.02)	(30.44)	(41.74)	(39.01)
	3	-467.39	-808.72	152.34	116.53
		(61.49)	(45.22)	(19.47)	(57.25)
	4	-370.86	-570.66	156.34	102.06
		(22.62)	(35.17)	(19.44)	(31.82)
	5	-450.14	-760.64	105.96	143.49
		(11.45)	(38.10)	(19.18)	(21.86)
	6	-494.94	-729.14	168.69	175.98
		(51.86)	(45.01)	(39.34)	(17.20)
2	1	-271.57	-539.50	95.81	212.38
		(51.21)	(26.25)	(33.09)	(54.98)
	2	-373.33	-658.48	103.34	200.40
		(37.88)	(83.82)	(25.83)	(52.27)
	3	-449.66	-715.08	196.50	264.77
		(33.44)	(29.69)	(36.88)	(27.67)
	4	-189.52	-425.75	88.93	93.09
		(24.71)	(48.42)	(15.85)	(31.33)
	5	-163.38	-464.33	95.42	131.29
		(36.18)	(9.17)	(42.18)	(24.24)
	6	-367.24	-556.36	163.17	157.39
		(31.25)	(54.90)	(37.22)	(54.18)
3	1	-270.39	-473.86	139.06	90.63
		(19.87)	(26.92)	(19.28)	(18.23)
	2	-274.82	-648.66	162.35	153.76
		(39.94)	(54.68)	(16.0)	(12.11)
	3	-327.59	-738.06	176.65	127.59
		(35.63)	(42.87)	(21.0)	(13.35)
	4	-232.03	-397.32	110.0	69.92
		(22.82)	(22.73)	(15.17)	(21.64)
	5	-277.31	-444.83	122.0	84.83
		(21.45)	(16.42)	(12.75)	(22.27)
	6	-298.01	-528.38	148.27	94.93
		(18.23)	(31.17)	(34.21)	(21.09)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
4	1	-278.98	-553.24	108.98	118.88
		(19.88)	(37.64)	(13.11)	(34.35)
	2	-345.57	-674.01	129.80	182.92
		(38.16)	(43.70)	(32.44)	(34.42)
	3	-410.77	-751.78	175.26	207.97
		(33.53)	(35.26)	(37.58)	(22.97)
	4	-240.37	-605.62	103.25	199.07
		(25.11)	(44.82)	(19.55)	(21.70)
	5	-314.56	-601.64	117.39	144.65
		(18.27)	(30.16)	(12.32)	(60.36)
	6	-384.66	-637.76	136.76	210.56
		(27.79)	(31.93)	(11.46)	(17.97)
6	1	-288.99	-581.12	99.41	80.31
		(25.31)	(44.25)	(16.36)	(27.53)
	2	-251.02	-531.20	89.57	129.31
		(28.34)	(77.77)	(27.30)	(22.04)
	3	-314.39	-840.81	216.18	54.13
		(74.02)	(68.72)	(46.42)	(18.44)
	4	-107.99	-386.85	55.69	158.39
		(39.73)	(39.46)	(14.79)	(17.14)
	5	-165.42	-320.79	37.08	134.70
		(18.96)	(17.19)	(16.10)	(19.52)
	6	-183.21	-408.60	54.48	166.55
		(13.61)	(67.73)	(15.42)	(13.01)
7	1	-259.08	-635.58	141.72	88.40
		(62.92)	(33.92)	(29.52)	(35.38)
	2	-328.63	-704.75	159.03	39.09
		(38.48)	(38.79)	(22.71)	(11.31)
	3	-278.18	-815.20	192.69	40.42
		(35.35)	(33.02)	(31.30)	(12.77)
	4	-256.51	-567.33	137.38	86.18
		(11.02)	(34.23)	(17.82)	(22.85)
	5	-283.83	-675.36	167.25	57.95
		(35.49)	(35.70)	(28.45)	(27.62)
	6	-288.95	-724.48	149.51	51.0
		(24.18)	(51.07)	(29.77)	(13.12)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
8	1	-403.56 (58.16)	-575.76 (22.45)	160.48 (32.31)	123.90 (46.59)
	2	-395.93 (42.86)	-631.40 (35.87)	186.17 (28.88)	201.70 (30.10)
	3	-405.10 (54.22)	-761.46 (58.52)	222.73 (43.89)	195.07 (120.37)
	4	-382.76 (33.75)	-581.38 (25.52)	181.31 (39.19)	118.77 (23.31)
	5	-367.03 (27.03)	-587.59 (20.71)	200.99 (49.79)	184.33 (27.57)
	6	-419.03 (74.60)	-722.81 (22.51)	195.85 (48.39)	180.18 (58.97)
9	1	-460.72 (52.97)	-768.94 (58.50)	189.02 (27.87)	44.62 (14.93)
	2	-493.46 (62.39)	-839.56 (54.82)	182.70 (15.57)	48.82 (25.03)
	3	-571.69 (35.57)	-843.35 (37.46)	284.19 (46.55)	56.72 (9.99)
	4	-460.59 (26.54)	-712.75 (36.13)	186.16 (17.58)	47.41 (26.79)
	5	-465.45 (44.03)	-742.86 (26.72)	238.06 (21.79)	42.56 (22.60)
	6	-542.10 (55.06)	-826.41 (36.03)	263.88 (51.26)	35.33 (10.95)
10	1	-349.72 (21.53)	-514.07 (32.22)	79.75 (19.78)	33.56 (18.49)
	2	-456.05 (62.62)	-587.41 (57.18)	152.19 (14.73)	79.49 (23.96)
	3	-431.38 (35.03)	-587.88 (26.59)	224.68 (25.17)	101.41 (11.10)
	4	-380.59 (24.47)	-486.39 (36.25)	93.31 (21.28)	56.07 (28.87)
	5	-479.51 (24.75)	-566.25 (32.56)	135.36 (20.30)	90.52 (17.20)
	6	-499.06 (27.96)	-619.78 (64.12)	174.43 (16.37)	77.52 (9.55)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
11	1	-305.14	-443.79	44.72	61.72
		(33.69)	(32.69)	(18.72)	(17.63)
	2	-406.81	-574.77	80.58	85.25
		(34.0)	(18.26)	(19.12)	(12.09)
	3	-409.68	-709.56	104.58	83.62
		(62.57)	(39.28)	(35.26)	(16.06)
	4	-254.35	-476.11	47.45	72.10
		(21.81)	(28.93)	(16.16)	(18.96)
	5	-332.80	-541.01	80.10	95.80
		(28.96)	(26.90)	(38.35)	(6.82)
	6	-419.51	-582.84	91.11	101.66
		(34.84)	(46.07)	(13.71)	(26.98)
16	1	-308.69	-533.28	114.94	135.93
		(26.89)	(25.35)	(15.17)	(5.33)
	2	-402.09	-605.97	112.35	103.57
		(47.10)	(34.91)	(27.08)	(47.03)
	3	-417.67	-627.15	140.66	96.12
		(48.93)	(25.69)	(32.45)	(11.01)
	4	-182.78	-360.59	87.15	161.56
		(80.87)	(40.84)	(27.62)	(60.99)
	5	-322.49	-477.77	80.37	70.36
		(34.91)	(11.60)	(28.19)	(21.28)
	6	-345.07	-497.10	85.97	110.57
		(39.03)	(41.40)	(16.52)	(12.64)
20	1	-341.04	-496.14	102.81	135.53
		(9.17)	(12.85)	(22.66)	(31.94)
	2	-353.18	-570.31	125.58	199.65
		(24.20)	(4.77)	(32.36)	(16.92)
	3	-387.83	-587.52	139.49	219.87
		(45.47)	(24.51)	(22.88)	(28.38)
	4	-130.34	-312.04	97.77	117.50
		(23.13)	(33.34)	(13.12)	(11.61)
	5	-245.46	-458.34	111.30	147.43
		(40.62)	(39.48)	(22.79)	(40.46)
	6	-351.23	-528.31	111.67	153.20
		(39.94)	(15.89)	(15.88)	(43.27)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
21	1	-308.63 (93.41)	-630.62 (30.56)	170.04 (20.76)	245.86 (46.75)
	2	-321.35 (39.33)	-721.41 (40.03)	240.43 (29.04)	180.75 (52.04)
	3	-339.55 (26.04)	-842.56 (31.67)	248.35 (29.27)	176.89 (39.88)
	4	-247.68 (39.20)	-471.39 (32.73)	158.47 (22.73)	175.42 (42.80)
	5	-217.03 (58.45)	-522.65 (43.83)	144.07 (40.17)	194.90 (66.44)
	6	-339.83 (59.97)	-621.15 (19.42)	174.48 (41.20)	238.42 (37.95)
22	1	-244.27 (62.65)	-526.92 (25.58)	48.16 (13.04)	129.97 (31.29)
	2	-371.91 (48.27)	-667.23 (24.98)	99.03 (15.79)	100.06 (40.69)
	3	-506.46 (58.14)	-736.46 (59.61)	180.12 (19.57)	155.97 (39.99)
	4	-152.50 (119.98)	-469.09 (42.83)	75.62 (18.99)	100.69 (29.92)
	5	-283.76 (64.92)	-584.63 (31.01)	76.71 (27.02)	98.43 (21.52)
	6	-335.40 (14.66)	-569.58 (25.28)	60.14 (18.44)	135.32 (24.51)
25	1	-382.37 (25.38)	-512.26 (25.85)	115.28 (20.54)	106.83 (33.41)
	2	-447.95 (36.35)	-569.28 (10.81)	175.97 (25.99)	179.46 (25.07)
	3	-445.75 (16.39)	-630.25 (28.62)	127.77 (31.68)	152.46 (31.65)
	4	-285.51 (17.56)	-440.68 (30.79)	86.48 (10.10)	116.43 (27.87)
	5	-357.89 (27.80)	-455.83 (53.12)	68.12 (22.28)	121.10 (18.54)
	6	-381.32 (35.85)	-510.92 (42.93)	97.21 (21.82)	141.11 (48.96)

Continued.

Subject	Condition	Contact	Flexion	Adduction	Internal Rotation
26	1	-277.68	-602.94	151.44	139.58
		(23.72)	(81.93)	(34.35)	(27.99)
	2	-345.02	-607.07	121.82	170.51
		(67.46)	(45.99)	(32.41)	(29.77)
	3	-351.20	-694.01	205.88	107.60
		(46.47)	(37.07)	(48.76)	(46.30)
	4	-262.35	-513.92	80.90	167.85
		(29.27)	(17.39)	(10.91)	(25.79)
	5	-281.10	-593.37	130.10	196.51
		(22.77)	(38.07)	(29.59)	(63.92)
	6	-324.65	-626.92	166.70	166.0
		(29.15)	(75.61)	(73.63)	(38.51)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AN

Female Subject Table Right Hip Angle

Female subject hip angle data.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
1	1	17.79 (1.02)	0.00 (0.0)	66.28 (2.12)	-30.97 (1.44)	-20.98 (0.83)	0.35 (2.05)	6.72 (2.80)
	2	6.69 (4.61)	131.42 (7.71)	124.96 (10.24)	-67.07 (2.86)	-42.70 (7.05)	57.19 (3.77)	85.01 (13.18)
	3	23.07 (3.20)	130.26 (6.28)	107.14 (9.06)	-41.71 (4.90)	-23.93 (3.60)	28.37 (8.14)	40.27 (12.77)
	4	13.39 (3.49)	0.00 (0.0)	62.13 (3.73)	-34.91 (0.0)	-25.93 (2.50)	0.19 (2.17)	9.05 (6.42)
	5	27.96 (0.99)	101.01 (4.67)	73.25 (4.01)	-14.71 (0.87)	-7.87 (4.43)	1.57 (4.25)	-5.65 (3.59)
	6	26.51 (0.87)	0.00 (0.0)	92.73 (1.51)	-41.81 (3.31)	-28.48 (3.68)	20.70 (2.96)	23.49 (13.68)
2	1	19.58 (3.56)	47.62 (5.88)	28.03 (2.43)	6.07 (0.79)	1.74 (0.67)	14.91 (2.28)	0.73 (1.97)
	2	24.03 (2.64)	76.02 (7.13)	51.99 (7.83)	4.24 (1.48)	2.26 (2.17)	11.49 (1.98)	0.07 (1.63)
	3	28.30 (2.37)	95.16 (4.83)	66.86 (6.17)	-2.29 (2.31)	-0.05 (1.82)	8.50 (0.93)	1.45 (1.50)
	4	13.96 (2.50)	34.34 (4.16)	14.40 (8.70)	-1.63 (1.09)	2.43 (1.86)	11.53 (1.46)	3.20 (0.74)
	5	16.85 (3.53)	40.27 (3.24)	21.45 (4.58)	3.27 (1.63)	2.08 (2.33)	15.90 (1.32)	3.99 (1.42)
	6	18.69 (1.72)	46.79 (3.97)	28.09 (4.72)	-1.85 (1.90)	1.57 (1.20)	9.78 (1.47)	2.73 (2.76)
3	1	24.68 (2.88)	91.63 (2.61)	66.95 (2.43)	-0.10 (1.36)	7.63 (1.79)	6.47 (3.95)	-8.29 (0.80)
	2	38.43 (2.83)	121.01 (2.68)	82.57 (4.99)	-12.75 (1.59)	-2.98 (1.90)	12.05 (1.93)	4.80 (1.85)
	3	39.96 (2.91)	123.22 (1.12)	83.26 (3.39)	-8.54 (1.84)	-1.78 (1.47)	7.08 (0.56)	-2.03 (1.05)
	4	17.44 (3.03)	70.25 (3.95)	52.80 (4.88)	0.76 (0.69)	8.70 (1.31)	11.18 (0.43)	-3.81 (3.69)
	5	22.40 (2.04)	101.87 (3.52)	79.47 (4.32)	-3.61 (1.94)	4.80 (1.69)	7.15 (2.01)	-3.06 (2.29)
	6	28.46 (6.53)	108.42 (3.49)	79.96 (3.85)	-5.67 (1.26)	2.67 (2.78)	6.92 (1.90)	1.30 (1.50)

Continued.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
4	1	27.13 (1.72)	81.61 (4.93)	53.70 (3.96)	-8.45 (1.82)	-3.89 (0.73)	2.03 (2.03)	-2.99 (1.98)
	2	29.86 (1.83)	105.62 (3.35)	75.75 (3.17)	-6.82 (1.13)	-1.01 (1.93)	5.28 (0.63)	-0.64 (2.12)
	3	33.24 (1.77)	109.56 (4.43)	76.32 (2.82)	-6.96 (1.44)	-2.43 (1.70)	6.99 (1.90)	1.56 (1.95)
	4	27.39 (1.63)	73.31 (1.32)	45.92 (1.96)	-8.61 (0.84)	-1.57 (0.84)	3.31 (1.09)	-0.64 (1.20)
	5	31.32 (4.07)	98.22 (4.39)	66.91 (8.15)	-7.59 (0.55)	-2.82 (1.23)	3.72 (1.45)	-1.23 (0.56)
	6	31.74 (1.59)	91.39 (5.02)	59.53 (3.93)	-7.98 (1.14)	-2.30 (1.78)	0.87 (2.27)	-0.96 (1.50)
6	1	7.36 (1.68)	35.75 (8.05)	28.38 (7.45)	-18.72 (7.12)	-8.52 (4.18)	-6.99 (3.40)	9.11 (3.05)
	2	14.30 (2.13)	37.63 (9.78)	21.25 (11.09)	-5.99 (1.59)	-2.33 (2.53)	-0.78 (0.80)	1.89 (2.24)
	3	14.10 (1.44)	88.72 (10.30)	74.62 (11.39)	-49.14 (3.60)	-24.23 (1.87)	15.42 (8.77)	49.52 (10.20)
	4	-4.32 (1.11)	6.63 (1.81)	7.35 (2.71)	-1.73 (0.92)	-2.46 (0.72)	4.89 (1.79)	5.58 (2.31)
	5	13.40 (1.82)	22.68 (3.13)	5.19 (1.66)	-3.50 (0.58)	-1.18 (1.72)	1.36 (1.26)	1.98 (2.05)
	6	14.20 (1.49)	28.75 (4.77)	10.59 (6.09)	-3.04 (1.35)	-1.22 (1.81)	0.84 (1.16)	3.22 (0.71)
7	1	22.34 (1.68)	76.72 (3.42)	54.38 (4.27)	-15.95 (1.67)	-5.06 (1.47)	8.16 (1.08)	3.39 (2.19)
	2	22.02 (2.40)	85.54 (2.12)	63.52 (3.92)	-20.54 (1.45)	-8.08 (2.16)	7.77 (0.91)	2.86 (1.33)
	3	25.64 (1.39)	91.89 (4.78)	66.25 (4.79)	-21.18 (1.94)	-9.74 (1.15)	10.28 (2.74)	3.14 (2.69)
	4	23.72 (2.91)	73.98 (3.66)	50.26 (4.13)	-18.14 (2.43)	-6.36 (2.15)	8.15 (1.56)	2.03 (1.08)
	5	22.52 (2.60)	82.39 (3.72)	59.87 (2.29)	-19.53 (0.72)	-7.40 (1.21)	9.02 (1.81)	2.25 (2.41)
	6	21.75 (1.61)	84.59 (2.98)	62.84 (2.81)	-19.23 (2.37)	-7.30 (2.19)	9.56 (0.93)	2.63 (1.20)

Continued.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
8	1	22.71	75.68	51.07	-6.34	-1.05	13.78	0.36
		(1.10)	(4.25)	(6.14)	(1.76)	(3.31)	(1.77)	(1.08)
	2	24.95	80.32	55.37	-5.47	-4.38	11.72	-2.10
		(3.13)	(3.57)	(2.73)	(2.26)	(1.07)	(1.76)	(0.96)
	3	29.57	93.26	63.70	-10.60	-8.57	12.03	0.41
		(4.39)	(2.44)	(4.85)	(4.38)	(3.83)	(0.86)	(1.70)
	4	24.28	72.55	48.27	-6.26	1.71	13.36	-0.58
		(4.44)	(2.16)	(5.33)	(2.52)	(1.68)	(1.40)	(1.36)
	5	25.09	79.62	54.90	-3.01	-3.10	12.31	-2.97
		(1.83)	(5.17)	(5.82)	(3.18)	(2.74)	(1.05)	(0.65)
	6	26.93	87.87	60.94	-7.69	-6.03	11.32	-1.97
		(1.12)	(4.64)	(5.19)	(1.93)	(1.52)	(2.25)	(2.0)
9	1	29.39	113.20	83.81	-6.74	-8.75	10.84	-19.79
		(2.57)	(2.47)	(3.57)	(1.28)	(2.88)	(1.29)	(2.80)
	2	26.92	114.37	87.45	-10.20	-12.13	8.71	-18.17
		(1.92)	(1.42)	(1.84)	(1.61)	(1.90)	(1.27)	(4.04)
	3	34.56	114.58	80.03	-16.50	-19.43	6.25	-11.84
		(2.71)	(5.45)	(7.84)	(4.84)	(5.56)	(3.24)	(1.40)
	4	30.26	107.45	77.19	-2.97	-11.58	7.84	-25.63
		(0.41)	(2.22)	(2.48)	(2.89)	(1.07)	(1.99)	(1.19)
	5	30.51	112.10	81.59	-21.05	-9.34	16.29	7.22
		(3.79)	(3.77)	(4.80)	(3.74)	(3.49)	(4.44)	(3.33)
	6	35.13	114.83	79.69	-18.14	-13.77	12.71	-1.55
		(1.98)	(4.30)	(3.65)	(3.78)	(2.21)	(3.39)	(5.40)
10	1	28.40	61.78	33.38	-4.49	-1.13	-6.15	-4.12
		(1.95)	(1.68)	(0.89)	(1.17)	(0.51)	(0.53)	(1.08)
	2	40.87	97.21	56.33	-15.87	-8.78	-0.93	1.80
		(4.33)	(6.15)	(2.43)	(2.63)	(1.60)	(1.79)	(1.43)
	3	42.47	104.72	62.25	-17.29	-12.15	-0.47	3.27
		(2.0)	(1.93)	(2.95)	(2.56)	(1.41)	(3.20)	(3.21)
	4	33.91	69.83	35.92	-8.47	-3.94	-5.59	-4.03
		(2.95)	(6.96)	(5.88)	(1.50)	(2.21)	(1.67)	(2.38)
	5	39.28	87.01	47.72	-15.72	-9.10	-3.09	-1.55
		(1.02)	(6.30)	(6.53)	(2.62)	(3.78)	(1.58)	(2.06)
	6	40.22	97.50	57.28	-17.45	-10.17	-0.57	2.69
		(3.30)	(4.24)	(5.42)	(2.33)	(3.13)	(1.51)	(1.83)

Continued.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
11	1	10.98 (0.48)	32.22 (2.54)	21.24 (2.75)	-7.23 (1.32)	-2.71 (1.56)	-4.12 (1.05)	-1.12 (1.34)
	2	14.93 (1.29)	52.07 (2.62)	37.14 (3.42)	-13.48 (0.98)	-8.34 (1.49)	-7.46 (1.12)	-4.33 (0.84)
	3	22.11 (0.76)	73.96 (6.91)	51.85 (7.16)	-16.03 (1.30)	-6.89 (2.96)	-2.20 (1.67)	3.21 (2.06)
	4	5.49 (2.26)	30.14 (2.07)	24.66 (2.37)	-5.99 (0.94)	-2.92 (1.49)	-5.36 (1.44)	-3.76 (1.96)
	5	14.87 (2.53)	46.81 (3.59)	31.94 (2.42)	-10.86 (1.34)	-6.78 (1.98)	-6.59 (1.43)	-2.58 (2.65)
	6	15.92 (2.77)	55.89 (3.41)	39.97 (2.97)	-13.90 (2.58)	-8.0 (1.56)	-7.73 (2.26)	-2.71 (1.59)
16	1	23.83 (4.44)	60.76 (5.81)	36.93 (2.98)	8.29 (2.91)	3.10 (2.89)	10.23 (3.52)	-3.55 (3.78)
	2	32.22 (2.52)	86.26 (2.29)	54.04 (2.90)	-7.42 (1.44)	-2.01 (1.27)	-2.19 (1.68)	-4.70 (2.46)
	3	38.77 (1.23)	101.47 (2.75)	62.70 (3.76)	-5.13 (0.83)	0.83 (2.51)	1.91 (1.56)	-4.20 (1.57)
	4	11.34 (2.86)	32.91 (4.90)	21.57 (2.92)	6.46 (4.97)	5.26 (3.58)	21.74 (2.28)	0.21 (1.26)
	5	21.83 (1.84)	47.70 (2.36)	25.87 (1.38)	-0.35 (1.45)	3.03 (1.33)	1.83 (0.91)	-2.24 (2.20)
	6	18.69 (3.08)	55.21 (9.39)	36.51 (7.47)	13.62 (1.99)	8.22 (4.18)	14.26 (2.81)	-3.01 (3.18)
20	1	8.66 (1.83)	17.53 (2.55)	1.63 (5.22)	-8.94 (0.65)	-0.07 (1.13)	5.42 (0.96)	5.19 (1.73)
	2	11.36 (1.38)	25.10 (3.26)	11.32 (6.31)	-10.52 (1.72)	-0.24 (2.22)	5.28 (1.11)	4.0 (2.74)
	3	15.60 (1.36)	32.43 (1.44)	16.83 (0.74)	-9.89 (0.59)	-0.28 (0.97)	8.04 (1.42)	7.86 (1.21)
	4	8.61 (1.57)	15.85 (1.99)	3.37 (3.77)	-8.34 (0.95)	0.08 (2.25)	2.87 (1.28)	1.77 (1.18)
	5	9.18 (1.37)	18.37 (0.47)	4.27 (5.59)	-10.05 (1.12)	-0.54 (3.90)	3.93 (3.07)	2.37 (2.49)
	6	9.66 (1.68)	21.14 (2.23)	4.35 (5.23)	-10.22 (0.71)	-2.03 (0.45)	5.41 (1.54)	4.41 (1.50)

Continued.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
21	1	15.94 (4.83)	69.45 (3.27)	53.51 (5.75)	-23.63 (1.94)	-11.25 (2.53)	-5.81 (3.50)	11.76 (2.91)
	2	19.83 (4.61)	76.44 (9.71)	56.61 (7.31)	-42.93 (3.97)	-18.66 (3.75)	-6.41 (6.57)	22.48 (8.90)
	3	25.18 (4.56)	93.25 (8.25)	68.07 (4.02)	-35.71 (4.52)	-15.22 (3.69)	1.08 (3.92)	27.44 (4.41)
	4	8.16 (2.33)	36.51 (4.98)	24.21 (9.74)	-28.02 (2.07)	-13.06 (1.83)	-26.38 (4.21)	7.20 (3.34)
	5	11.79 (3.77)	40.31 (9.63)	23.91 (14.79)	-33.38 (5.03)	-16.25 (3.31)	-29.55 (5.0)	5.39 (2.76)
	6	13.49 (4.14)	55.98 (9.40)	42.39 (5.45)	-40.83 (3.13)	-19.43 (3.33)	-19.64 (4.94)	15.90 (4.19)
22	1	17.13 (1.78)	34.75 (4.27)	13.91 (8.29)	-8.59 (1.86)	2.87 (3.26)	5.61 (1.29)	1.31 (2.46)
	2	18.49 (0.88)	41.96 (2.58)	22.65 (3.38)	-6.29 (2.05)	1.79 (2.91)	6.93 (0.66)	-0.94 (2.18)
	3	24.53 (1.76)	63.68 (12.17)	39.16 (11.24)	-2.02 (3.29)	6.26 (3.71)	6.56 (4.23)	-2.95 (3.81)
	4	11.39 (2.69)	24.64 (4.14)	11.30 (4.06)	-2.49 (1.86)	0.41 (3.73)	16.30 (1.29)	3.10 (1.13)
	5	15.75 (1.07)	33.81 (2.37)	18.05 (2.04)	-1.57 (2.51)	2.08 (3.06)	17.35 (1.17)	1.63 (2.33)
	6	20.46 (1.14)	44.16 (2.56)	19.70 (10.66)	-9.89 (2.29)	0.99 (1.58)	5.59 (0.91)	1.64 (2.10)
25	1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.46 (1.38)	6.54 (4.79)	12.34 (2.74)	-11.45 (3.44)
	2	32.76 (0.99)	97.71 (5.98)	64.95 (5.43)	-4.61 (1.89)	3.24 (2.03)	9.69 (4.16)	-1.66 (3.80)
	3	31.91 (2.77)	104.90 (2.36)	72.99 (2.71)	2.05 (3.18)	6.54 (2.17)	3.13 (3.07)	-14.40 (4.42)
	4	20.03 (3.08)	42.21 (3.76)	22.18 (2.39)	3.03 (5.12)	2.79 (3.14)	17.52 (3.81)	-7.59 (3.41)
	5	27.70 (3.09)	64.05 (6.40)	36.35 (6.35)	-3.27 (1.85)	5.39 (2.11)	8.12 (4.46)	-3.50 (2.90)
	6	24.86 (2.27)	71.12 (7.86)	46.26 (5.93)	14.17 (2.14)	13.88 (1.14)	7.37 (1.02)	-12.0 (5.61)

Continued.

Subj	Cond	Contact	Flexion	Flexion ROM	Abduction	Abduction ROM	Internal Rotat	Internal Rotat ROM
26	1	15.44	44.58	29.15	-3.37	3.86	10.08	1.73
		(1.76)	(5.58)	(5.33)	(1.41)	(0.62)	(1.90)	(2.33)
	2	16.08	50.31	34.23	4.82	9.14	16.94	-1.30
		(1.40)	(4.23)	(3.34)	(2.35)	(2.91)	(2.06)	(1.27)
	3	19.69	83.95	69.37	0.92	4.98	7.09	-5.80
		(2.44)	(11.37)	(14.35)	(3.37)	(3.85)	(4.61)	(5.40)
	4	12.70	32.20	19.50	-4.05	2.35	18.67	2.37
		(2.34)	(3.65)	(1.93)	(2.53)	(1.96)	(1.40)	(2.67)
	5	16.91	48.83	31.91	2.63	8.06	14.53	-3.71
		(1.68)	(4.59)	(4.71)	(1.87)	(1.16)	(2.65)	(1.86)
	6	17.90	65.80	47.87	1.21	6.82	13.62	0.02
		(0.97)	(5.12)	(4.53)	(2.31)	(2.18)	(0.95)	(1.28)

Note: Angle units is degrees; values in parenthesis are standard deviation.

Appendix AO

Female Subject Table Right Hip Angular Velocity

Female subject hip angular velocity data.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
1	1	242.22 (6.66)	349.63 (17.33)	-45.23 (5.84)	37.53 (17.74)
	2	295.26 (26.41)	565.43 (30.28)	-106.09 (21.50)	70.28 (18.16)
	3	318.49 (35.55)	702.38 (39.77)	-73.15 (13.17)	29.64 (8.61)
	4	201.39 (22.55)	340.34 (38.30)	-54.90 (10.68)	28.93 (14.56)
	5	236.68 (26.50)	496.05 (29.32)	-52.96 (14.58)	36.15 (4.27)
	6	250.89 (49.42)	511.59 (33.41)	-69.09 (15.31)	26.83 (10.37)
2	1	113.77 (46.80)	322.56 (39.53)	-74.05 (10.23)	136.59 (17.53)
	2	255.28 (29.65)	540.74 (90.75)	-51.36 (22.28)	154.76 (56.34)
	3	362.0 (53.50)	629.55 (38.21)	-83.33 (22.13)	89.30 (14.77)
	4	78.04 (25.59)	214.60 (64.69)	-59.37 (18.68)	106.64 (25.18)
	5	63.20 (16.97)	281.28 (26.93)	-81.95 (19.92)	144.16 (28.30)
	6	207.57 (42.08)	308.19 (49.93)	-57.53 (12.74)	85.45 (26.79)
3	1	187.74 (22.68)	456.0 (25.81)	-36.05 (8.20)	52.01 (26.72)
	2	219.03 (32.87)	658.63 (39.48)	-121.30 (27.79)	84.89 (12.54)
	3	289.62 (16.41)	738.93 (21.11)	-130.43 (9.94)	92.68 (22.58)
	4	170.77 (26.96)	330.75 (41.52)	-36.39 (10.83)	42.87 (14.95)
	5	238.58 (8.92)	430.37 (15.31)	-51.84 (12.94)	47.10 (19.52)
	6	236.29 (29.93)	538.80 (7.85)	-70.38 (26.61)	85.43 (29.02)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
4	1	171.34	362.41	-73.26	104.90
		(11.48)	(43.93)	(13.57)	(21.90)
	2	248.60	482.16	-61.18	104.66
		(12.82)	(49.39)	(23.30)	(34.19)
	3	282.03	539.87	-74.12	105.95
		(26.78)	(16.85)	(26.38)	(34.30)
	4	156.64	393.21	-69.42	148.47
		(23.68)	(15.24)	(25.15)	(15.44)
	5	207.91	432.51	-65.80	99.92
		(6.98)	(43.20)	(21.04)	(35.40)
	6	206.04	411.18	-52.57	116.40
		(18.29)	(29.51)	(12.73)	(39.18)
6	1	142.97	402.84	-58.92	112.46
		(15.12)	(55.06)	(10.62)	(21.44)
	2	119.94	289.21	-77.87	132.35
		(15.69)	(74.59)	(25.61)	(46.73)
	3	277.61	671.48	-178.67	125.27
		(21.44)	(46.54)	(127.09)	(60.51)
	4	3.22	196.64	-60.17	149.15
		(13.68)	(22.26)	(3.97)	(16.38)
	5	7.79	132.15	-52.55	111.93
		(7.54)	(33.25)	(6.66)	(55.46)
	6	46.76	209.83	-57.87	125.17
		(14.17)	(51.18)	(13.49)	(15.34)
7	1	96.04	423.87	-107.48	136.05
		(28.64)	(31.50)	(10.32)	(22.79)
	2	168.91	446.09	-103.40	81.46
		(28.42)	(30.31)	(19.36)	(15.70)
	3	135.78	587.62	-111.23	83.16
		(18.69)	(23.84)	(14.88)	(11.14)
	4	114.63	371.70	-101.71	113.42
		(34.29)	(17.75)	(27.73)	(33.49)
	5	134.64	454.92	-123.75	117.47
		(17.89)	(22.34)	(38.08)	(35.24)
	6	128.15	524.75	-115.62	78.16
		(17.62)	(31.09)	(11.08)	(12.15)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
8	1	176.75 (45.82)	350.17 (26.24)	-77.67 (23.33)	63.53 (24.28)
	2	199.75 (32.72)	447.97 (49.70)	-106.86 (25.58)	80.67 (9.46)
	3	252.45 (33.67)	562.51 (41.42)	-135.22 (13.65)	75.08 (20.86)
	4	173.70 (20.36)	355.92 (47.91)	-54.01 (12.07)	75.66 (16.35)
	5	195.86 (16.39)	398.56 (13.91)	-102.60 (30.45)	96.07 (18.46)
	6	247.92 (59.35)	536.84 (13.96)	-150.11 (21.30)	88.29 (18.61)
9	1	335.26 (44.53)	624.20 (35.13)	-164.69 (25.93)	33.24 (17.29)
	2	325.59 (48.97)	677.42 (25.72)	-152.49 (14.41)	34.28 (22.34)
	3	345.09 (26.01)	666.67 (40.08)	-245.26 (40.14)	63.80 (16.66)
	4	283.62 (19.69)	536.43 (16.85)	-146.86 (16.36)	39.87 (26.63)
	5	265.95 (36.47)	630.59 (19.49)	-160.19 (35.67)	87.62 (27.34)
	6	338.19 (44.65)	674.93 (22.21)	-234.75 (67.65)	90.75 (20.82)
10	1	184.91 (16.78)	269.33 (39.29)	-50.36 (7.32)	36.22 (12.83)
	2	260.80 (43.75)	394.33 (31.77)	-114.55 (24.68)	64.66 (23.47)
	3	236.77 (19.43)	441.35 (26.25)	-166.17 (12.91)	37.91 (6.85)
	4	218.90 (16.98)	274.48 (38.30)	-73.88 (10.31)	68.55 (13.68)
	5	280.99 (30.43)	349.75 (67.09)	-110.29 (30.59)	68.03 (52.12)
	6	298.14 (32.38)	408.01 (12.87)	-142.64 (36.97)	71.13 (22.01)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
11	1	115.86 (27.35)	217.79 (16.54)	-46.72 (12.98)	67.58 (16.31)
	2	180.16 (10.98)	392.49 (34.02)	-88.44 (24.12)	57.94 (11.66)
	3	207.15 (36.76)	596.74 (34.85)	-94.15 (31.0)	62.38 (12.58)
	4	106.02 (20.55)	252.35 (27.13)	-40.15 (24.09)	37.61 (14.64)
	5	135.48 (35.90)	304.40 (34.66)	-60.54 (29.28)	64.25 (20.22)
	6	185.22 (8.58)	419.97 (24.78)	-78.42 (12.80)	53.52 (12.65)
16	1	202.03 (18.58)	349.04 (19.17)	-65.10 (13.63)	138.23 (28.50)
	2	230.67 (27.68)	424.39 (38.24)	-102.77 (26.63)	40.04 (11.25)
	3	270.48 (28.49)	504.12 (36.74)	-133.14 (13.67)	46.42 (13.49)
	4	99.85 (40.59)	223.03 (44.99)	-91.06 (25.04)	110.13 (39.85)
	5	141.44 (26.93)	236.83 (25.42)	-69.42 (19.22)	88.63 (25.74)
	6	209.70 (33.08)	312.43 (44.76)	-62.41 (14.19)	98.16 (15.77)
20	1	85.36 (14.48)	118.23 (24.33)	-70.02 (8.37)	110.85 (14.70)
	2	103.92 (18.83)	161.55 (35.07)	-77.42 (15.82)	127.24 (26.91)
	3	100.06 (18.28)	252.08 (11.03)	-99.30 (22.47)	231.69 (11.64)
	4	7.10 (15.67)	100.18 (19.96)	-57.77 (22.91)	72.70 (13.45)
	5	46.87 (17.53)	119.89 (13.41)	-45.49 (19.80)	77.39 (27.62)
	6	99.40 (16.25)	145.84 (25.68)	-81.07 (11.68)	119.48 (31.57)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
21	1	179.71 (56.85)	498.19 (38.56)	-152.51 (32.58)	148.50 (40.15)
	2	190.18 (36.82)	552.43 (36.03)	-180.06 (31.35)	172.88 (29.83)
	3	163.56 (18.72)	656.83 (19.19)	-211.09 (34.10)	189.64 (81.18)
	4	124.46 (47.45)	341.16 (43.37)	-85.05 (27.29)	176.11 (21.39)
	5	108.27 (46.39)	360.50 (54.81)	-86.96 (20.89)	186.22 (43.43)
	6	180.58 (32.11)	475.51 (5.80)	-124.86 (40.26)	190.56 (61.03)
22	1	77.12 (8.57)	221.35 (52.75)	-109.78 (37.13)	110.61 (29.45)
	2	154.64 (44.51)	313.13 (66.14)	-112.73 (29.11)	78.89 (18.77)
	3	221.78 (49.16)	422.22 (48.22)	-198.96 (42.71)	111.57 (29.79)
	4	69.53 (43.81)	167.48 (19.04)	-66.72 (27.90)	91.28 (10.98)
	5	82.59 (31.24)	257.92 (56.34)	-90.58 (21.28)	134.17 (46.47)
	6	115.25 (22.84)	338.42 (22.50)	-173.33 (22.84)	145.62 (29.77)
25	1	0.00 (0.00)	0.00 (0.00)	-49.61 (17.40)	43.04 (18.80)
	2	218.50 (18.29)	413.49 (27.38)	-129.95 (28.24)	61.68 (9.85)
	3	171.36 (14.53)	493.18 (25.27)	-81.47 (29.81)	126.26 (84.05)
	4	107.44 (10.47)	238.59 (7.24)	-60.60 (10.43)	57.56 (22.92)
	5	185.66 (18.29)	277.61 (37.05)	-52.45 (11.33)	47.16 (20.17)
	6	173.62 (16.76)	351.88 (21.44)	-51.94 (19.43)	66.44 (33.16)

Continued.

Subject	Condition	Contact	Flexion	Abduction	Internal Rotation
26	1	72.92	412.89	-121.21	156.19
		(5.55)	(59.96)	(6.34)	(27.87)
	2	114.97	400.11	-100.51	184.36
		(33.75)	(43.80)	(21.60)	(29.59)
	3	133.67	546.29	-116.97	155.0
		(32.17)	(28.35)	(36.13)	(32.96)
	4	52.56	263.17	-95.70	133.53
		(18.01)	(41.85)	(12.33)	(24.71)
	5	95.85	386.10	-106.59	146.97
		(22.73)	(52.98)	(32.91)	(34.99)
	6	120.15	453.30	-127.53	197.88
		(27.70)	(42.96)	(41.54)	(36.94)

Note: Angular velocity units is degrees•s^{-1}; values in parenthesis are standard deviation.

Appendix AP

Female Subject Table GRF Data

Female subject GRF force data.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
1	1	-1.18	0.01	2.32	0.01	3.16	0.06	449.53	33.69	0.87
		(0.07)	(0.0)	(0.14)	(0.0)	(0.40)	(0.01)	(160.67)	(14.39)	(0.03)
	2	-1.29	0.0	2.40	0.0	3.17	0.05	668.43	47.71	0.63
		(0.17)	(0.0)	(0.13)	(0.0)	(0.62)	(0.01)	(311.67)	(21.59)	(0.02)
	3	-1.68	0.01	2.90	0.0	4.0	0.04	679.13	121.08	0.54
		(0.14)	(0.0)	(0.11)	(0.0)	(0.40)	(0.0)	(277.92)	(70.04)	(0.05)
	4	-1.01	0.01	1.99	0.01	3.01	0.06	263.28	37.23	0.76
		(0.06)	(0.0)	(0.14)	(0.0)	(0.50)	(0.01)	(90.24)	(12.61)	(0.04)
	5	-1.35	0.02	2.65	0.01	3.56	0.04	432.31	63.31	0.68
		(0.48)	(0.03)	(0.11)	(0.0)	(0.56)	(0.0)	(91.30)	(26.80)	(0.02)
	6	-1.34	0.01	2.32	0.0	2.85	0.04	832.14	57.74	0.52
		(0.13)	(0.0)	(0.18)	(0.0)	(0.56)	(0.01)	(780.13)	(27.41)	(0.01)
2	1	-2.31	0.01	4.57	0.01	7.12	0.05	659.27	152.52	1.0
		(0.07)	(0.0)	(0.30)	(0.0)	(0.32)	(0.0)	(277.76)	(24.86)	(0.06)
	2	-2.05	0.01	4.09	0.01	5.78	0.04	948.15	166.21	0.77
		(0.16)	(0.0)	(0.33)	(0.0)	(0.58)	(0.0)	(709.45)	(28.02)	(0.03)
	3	-2.29	0.01	4.01	0.01	4.66	0.04	765.23	161.32	0.64
		(0:20)	(0.0)	(0.47)	(0.0)	(0.22)	(0.0)	(640.0)	(25.52)	(0.02)
	4	-1.59	0.01	3.72	0.01	10.19	0.08	308.66	125.92	1.78
		(0.22)	(0.0)	(0.73)	(0.0)	(0.49)	(0.01)	(121.34)	(12.47)	(0.13)
	5	-1.30	0.01	2.66	0.01	8.86	0.06	265.42	168.69	1.28
		(0.10)	(0.0)	(0.19)	(0.0)	(0.72)	(0.01)	(66.71)	(37.70)	(0.10)
	6	-2.06	0.01	4.42	0.01	6.03	0.06	684.29	112.89	1.10
		(0.33)	(0.0)	(0.47)	(0.0)	(0.95)	(0.01)	(486.38)	(83.81)	(0.13)
3	1	-0.82	0.01	2.48	0.01	4.19	0.07	193.86	51.81	1.10
		(0.06)	(0.0)	(0.04)	(0.0)	(0.54)	(0.02)	(46.40)	(14.09)	(0.03)
	2	-1.12	0.01	2.51	0.01	4.96	0.04	219.97	141.50	0.80
		(0.13)	(0.0)	(0.26)	(0.0)	(0.90)	(0.0)	(62.90)	(55.04)	(0.01)
	3	-1.14	0.01	2.32	0.01	4.50	0.03	573.74	139.47	0.64
		(0.08)	(0.0)	(0.19)	(0.0)	(0.68)	(0.0)	(346.63)	(38.20)	(0.02)
	4	-0.84	0.01	2.97	0.04	5.73	0.09	120.18	55.67	1.49
		(0.08)	(0.0)	(1.55)	(0.05)	(0.45)	(0.01)	(48.82)	(15.45)	(0.06)
	5	-0.90	0.01	2.44	0.01	3.92	0.08	166.85	37.64	1.16
		(0.07)	(0.0)	(0.20)	(0.0)	(0.22)	(0.0)	(24.73)	(5.95)	(0.04)
	6	-0.89	0.01	2.38	0.01	4.06	0.06	213.04	64.03	0.99
		(0.10)	(0.0)	(0.11)	(0.0)	(0.63)	(0.01)	(44.31)	(20.05)	(0.02)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
4	1	-1.53 (0.19)	0.01 (0.0)	3.0 (0.34)	0.01 (0.0)	6.36 (0.76)	0.07 (0.02)	409.01 (125.99)	111.94 (33.74)	1.18 (0.05)
	2	-1.43 (0.08)	0.01 (0.0)	2.79 (0.10)	0.01 (0.0)	4.51 (0.36)	0.04 (0.0)	450.14 (203.43)	82.94 (21.62)	0.80 (0.05)
	3	-1.57 (0.12)	0.01 (0.0)	2.96 (0.16)	0.01 (0.0)	4.51 (0.38)	0.03 (0.0)	436.62 (116.18)	116.16 (19.34)	0.65 (0.02)
	4	-1.04 (0.16)	0.01 (0.0)	1.97 (0.08)	0.04 (0.05)	7.19 (0.53)	0.09 (0.01)	504.79 (371.20)	205.05 (55.41)	1.35 (0.03)
	5	-1.34 (0.17)	0.01 (0.0)	2.72 (0.14)	0.01 (0.0)	5.53 (0.81)	0.08 (0.0)	351.68 (89.06)	105.08 (44.83)	1.03 (0.04)
	6	-1.48 (0.08)	0.01 (0.0)	3.08 (0.28)	0.01 (0.0)	5.03 (0.84)	0.06 (0.01)	290.41 (42.16)	94.13 (25.40)	0.84 (0.05)
6	1	-1.36 (0.52)	0.04 (0.03)	3.77 (0.34)	0.01 (0.0)	9.02 (1.09)	0.04 (0.0)	666.47 (445.29)	296.28 (116.68)	0.99 (0.03)
	2	-1.31 (0.22)	0.01 (0.0)	2.36 (0.20)	0.01 (0.0)	5.66 (0.48)	0.05 (0.01)	305.22 (66.45)	135.21 (44.69)	0.65 (0.06)
	3	-1.05 (0.40)	0.03 (0.02)	2.99 (0.37)	0.0 (0.0)	7.17 (0.46)	0.03 (0.0)	2344.76 (1031.58)	270.91 (36.33)	0.60 (0.02)
	4	-1.29 (0.28)	0.07 (0.06)	3.26 (0.69)	0.01 (0.01)	15.36 (2.15)	0.05 (0.01)	521.17 (314.83)	348.51 (23.19)	2.13 (0.21)
	5	-1.32 (0.10)	0.01 (0.0)	2.73 (0.26)	0.01 (0.0)	10.49 (1.82)	0.07 (0.0)	279.52 (137.34)	148.44 (40.76)	1.63 (0.17)
	6	-1.79 (0.40)	0.01 (0.0)	3.50 (0.68)	0.01 (0.0)	9.30 (1.71)	0.06 (0.01)	331.90 (17.86)	164.34 (33.91)	1.28 (0.15)
7	1	-1.07 (0.15)	0.01 (0.0)	2.30 (0.23)	0.01 (0.0)	6.60 (0.76)	0.04 (0.0)	507.27 (219.23)	211.11 (35.86)	0.99 (0.03)
	2	-1.25 (0.20)	0.01 (0.0)	2.45 (0.33)	0.01 (0.0)	4.40 (0.25)	0.04 (0.0)	630.17 (530.29)	121.32 (22.14)	0.72 (0.01)
	3	-1.68 (0.11)	0.01 (0.0)	2.87 (0.08)	0.01 (0.0)	5.44 (0.38)	0.03 (0.0)	595.70 (280.70)	218.68 (34.30)	0.58 (0.01)
	4	-0.79 (0.05)	0.02 (0.02)	1.81 (0.11)	0.01 (0.0)	6.08 (0.42)	0.04 (0.01)	239.66 (66.96)	170.84 (36.18)	1.15 (0.02)
	5	-1.38 (0.15)	0.01 (0.0)	2.82 (0.24)	0.01 (0.0)	6.70 (0.91)	0.04 (0.0)	558.05 (193.93)	224.99 (57.29)	0.85 (0.06)
	6	-1.56 (0.14)	0.01 (0.0)	3.27 (0.22)	0.01 (0.0)	5.69 (0.37)	0.04 (0.0)	489.67 (196.80)	177.30 (22.95)	0.66 (0.02)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
8	1	-1.41	0.01	3.11	0.01	5.42	0.06	494.33	83.21	1.02
		(0.13)	(0.0)	(0.29)	(0.0)	(0.51)	(0.01)	(199.02)	(19.46)	(0.06)
	2	-1.33	0.01	2.87	0.01	5.18	0.05	372.60	115.74	0.74
		(0.16)	(0.0)	(0.17)	(0.0)	(0.85)	(0.01)	(143.31)	(52.80)	(0.05)
	3	-1.64	0.01	3.54	0.01	4.96	0.04	491.56	166.28	0.61
		(0.24)	(0.0)	(0.16)	(0.0)	(0.39)	(0.01)	(273.66)	(60.50)	(0.02)
	4	-1.60	0.01	3.99	0.02	4.83	0.06	428.40	85.48	1.07
		(0.32)	(0.0)	(1.94)	(0.02)	(0.72)	(0.01)	(243.77)	(35.54)	(0.07)
	5	-1.28	0.01	2.77	0.01	5.28	0.06	301.96	104.18	0.77
		(0.23)	(0.0)	(0.30)	(0.0)	(0.77)	(0.01)	(25.21)	(40.63)	(0.03)
	6	-1.37	0.01	3.22	0.01	4.73	0.05	510.26	123.87	0.67
		(0.09)	(0.0)	(0.24)	(0.0)	(1.08)	(0.01)	(215.94)	(52.62)	(0.02)
9	1	-1.31	0.0	2.52	0.0	7.09	0.03	309.94	332.74	1.07
		(0.23)	(0.0)	(0.24)	(0.0)	(1.12)	(0.01)	(65.57)	(213.14)	(0.04)
	2	-1.44	0.01	3.34	0.01	5.43	0.03	752.35	182.52	0.78
		(0.24)	(0.0)	(1.74)	(0.01)	(0.45)	(0.0)	(880.80)	(28.79)	(0.02)
	3	-1.46	0.0	2.67	0.0	5.05	0.03	1753.32	190.97	0.62
		(0.14)	(0.0)	(0.27)	(0.0)	(0.53)	(0.0)	(489.72)	(50.73)	(0.03)
	4	-1.31	0.01	2.48	0.0	6.50	0.04	846.76	216.31	1.08
		(0.06)	(0.0)	(0.17)	(0.0)	(1.0)	(0.0)	(465.54)	(46.75)	(0.03)
	5	-1.71	0.01	2.93	0.01	5.96	0.04	892.91	264.35	0.78
		(0.12)	(0.0)	(0.38)	(0.0)	(1.08)	(0.0)	(898.89)	(67.52)	(0.03)
	6	-1.55	0.0	2.60	0.0	5.09	0.03	1893.30	195.44	0.65
		(0.14)	(0.0)	(0.14)	(0.0)	(0.77)	(0.0)	(1221.60)	(65.76)	(0.02)
10	1	-0.76	0.01	2.22	0.01	3.38	0.08	194.59	28.85	0.93
		(0.21)	(0.0)	(0.26)	(0.01)	(0.11)	(0.01)	(107.15)	(3.83)	(0.05)
	2	-1.15	0.01	3.33	0.01	2.87	0.07	307.35	28.17	0.74
		(0.34)	(0.0)	(0.53)	(0.0)	(0.24)	(0.02)	(130.04)	(5.16)	(0.05)
	3	-1.14	0.01	3.27	0.01	2.35	0.07	295.44	21.62	0.60
		(0.11)	(0.0)	(0.27)	(0.0)	(0.25)	(0.01)	(112.16)	(9.63)	(0.03)
	4	-0.84	0.01	2.62	0.01	4.27	0.09	213.48	37.32	1.08
		(0.20)	(0.0)	(0.34)	(0.0)	(0.86)	(0.0)	(45.78)	(16.48)	(0.08)
	5	-0.91	0.01	2.90	0.01	3.22	0.08	254.53	25.54	0.77
		(0.16)	(0.0)	(0.26)	(0.0)	(0.42)	(0.01)	(62.92)	(10.66)	(0.04)
	6	-0.84	0.01	2.87	0.01	2.68	0.07	245.19	23.85	0.65
		(0.20)	(0.0)	(0.37)	(0.0)	(0.42)	(0.0)	(56.81)	(10.26)	(0.02)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
11	1	-0.63	0.03	2.65	0.01	4.69	0.08	216.82	42.59	0.98
		(0.16)	(0.06)	(0.12)	(0.0)	(0.62)	(0.0)	(68.67)	(12.68)	(0.09)
	2	-0.95	0.01	3.48	0.01	3.71	0.06	353.31	40.70	0.67
		(0.14)	(0.0)	(0.27)	(0.0)	(0.58)	(0.01)	(116.32)	(20.03)	(0.02)
	3	-1.12	0.01	3.59	0.01	4.06	0.04	466.64	94.39	0.55
		(0.17)	(0.0)	(0.45)	(0.0)	(0.33)	(0.0)	(134.63)	(24.93)	(0.02)
	4	-0.89	0.01	2.67	0.01	4.24	0.08	217.58	41.35	1.08
		(0.08)	(0.0)	(0.23)	(0.0)	(0.55)	(0.01)	(31.54)	(12.46)	(0.12)
	5	-0.93	0.01	3.19	0.02	4.69	0.08	204.46	43.65	0.92
		(0.27)	(0.0)	(0.59)	(0.0)	(0.83)	(0.0)	(37.62)	(13.04)	(0.11)
	6	-0.92	0.01	3.40	0.01	3.65	0.06	433.64	51.0	0.63
		(0.17)	(0.0)	(0.28)	(0.0)	(0.50)	(0.01)	(152.37)	(22.15)	(0.04)
16	1	-1.64	0.01	3.03	0.01	7.46	0.06	320.26	128.79	1.31
		(0.06)	(0.0)	(0.28)	(0.0)	(0.73)	(0.0)	(74.41)	(15.32)	(0.05)
	2	-1.44	0.01	3.50	0.01	3.76	0.06	435.35	46.40	0.88
		(0.11)	(0.0)	(0.14)	(0.0)	(0.74)	(0.0)	(122.70)	(23.74)	(0.09)
	3	-1.52	0.01	3.69	0.01	3.43	0.05	526.47	55.76	0.64
		(0.16)	(0.0)	(0.22)	(0.0)	(0.51)	(0.01)	(238.13)	(19.42)	(0.03)
	4	-1.13	0.05	0.0	0.0	8.46	0.07	0.0	114.32	1.57
		(0.36)	(0.05)	(0.0)	(0.0)	(1.49)	(0.01)	(0.0)	(44.61)	(0.21)
	5	-1.10	0.01	2.31	0.01	6.09	0.07	272.60	76.77	1.31
		(0.07)	(0.0)	(0.11)	(0.0)	(0.64)	(0.01)	(82.72)	(16.12)	(0.07)
	6	-1.51	0.01	3.22	0.01	6.52	0.06	396.36	97.96	1.27
		(0.11)	(0.0)	(0.11)	(0.0)	(0.31)	(0.0)	(112.06)	(16.06)	(0.10)
20	1	-1.36	0.01	3.54	0.01	6.85	0.07	379.77	84.93	1.05
		(0.14)	(0.0)	(0.22)	(0.0)	(0.64)	(0.01)	(54.34)	(18.16)	(0.11)
	2	-1.40	0.01	4.42	0.01	6.04	0.07	323.44	100.72	0.70
		(0.06)	(0.0)	(0.33)	(0.0)	(0.25)	(0.0)	(48.05)	(8.62)	(0.04)
	3	-1.47	0.01	4.23	0.01	5.65	0.05	567.70	123.34	0.55
		(0.13)	(0.0)	(0.16)	(0.0)	(0.36)	(0.0)	(162.61)	(14.58)	(0.04)
	4	-0.78	0.02	3.16	0.02	7.72	0.10	175.74	64.32	1.51
		(0.24)	(0.0)	(0.08)	(0.0)	(0.46)	(0.01)	(24.64)	(9.45)	(0.11)
	5	-1.37	0.01	4.20	0.02	6.54	0.09	266.29	58.15	1.13
		(0.18)	(0.0)	(0.14)	(0.0)	(0.93)	(0.01)	(47.96)	(18.16)	(0.06)
	6	-1.43	0.01	4.21	0.01	7.23	0.07	370.79	104.74	0.97
		(0.19)	(0.0)	(0.52)	(0.0)	(0.30)	(0.01)	(43.26)	(9.44)	(0.03)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
21	1	-2.04 (0.16)	0.01 (0.0)	4.0 (0.31)	0.01 (0.0)	7.17 (0.58)	0.05 (0.01)	665.43 (340.34)	159.76 (38.72)	1.18 (0.06)
	2	-1.83 (0.30)	0.01 (0.0)	3.83 (0.49)	0.01 (0.0)	6.56 (1.0)	0.04 (0.0)	696.71 (257.67)	198.60 (60.31)	0.83 (0.07)
	3	-1.75 (0.13)	0.01 (0.0)	3.82 (0.38)	0.01 (0.0)	6.60 (0.97)	0.04 (0.0)	484.73 (87.84)	270.74 (47.78)	0.65 (0.05)
	4	-2.32 (0.59)	0.01 (0.0)	4.75 (1.02)	0.01 (0.0)	11.47 (1.68)	0.07 (0.01)	455.0 (109.32)	170.26 (30.10)	1.81 (0.11)
	5	-1.64 (0.10)	0.01 (0.0)	3.39 (0.20)	0.01 (0.0)	7.97 (0.34)	0.07 (0.0)	311.83 (88.17)	130.33 (4.92)	1.40 (0.14)
	6	-1.76 (0.34)	0.01 (0.0)	3.76 (0.61)	0.01 (0.0)	7.88 (1.13)	0.05 (0.0)	487.76 (191.42)	201.42 (87.15)	1.14 (0.08)
22	1	-1.82 (0.28)	0.01 (0.0)	4.39 (0.44)	0.01 (0.0)	6.66 (0.88)	0.07 (0.01)	350.23 (112.73)	73.74 (21.67)	1.19 (0.08)
	2	-1.68 (0.26)	0.01 (0.0)	4.55 (0.40)	0.01 (0.0)	4.89 (0.51)	0.06 (0.0)	358.39 (34.20)	69.34 (13.84)	0.71 (0.05)
	3	-1.61 (0.17)	0.01 (0.0)	3.55 (0.19)	0.01 (0.0)	4.27 (0.39)	0.04 (0.0)	658.39 (372.77)	101.82 (16.95)	0.60 (0.07)
	4	-1.40 (0.55)	0.01 (0.0)	3.75 (0.76)	0.01 (0.0)	8.41 (0.97)	0.09 (0.01)	433.07 (289.21)	77.30 (19.40)	1.77 (0.17)
	5	-2.14 (0.28)	0.01 (0.0)	4.51 (0.27)	0.01 (0.01)	7.14 (0.65)	0.06 (0.01)	629.44 (394.40)	108.06 (24.15)	1.22 (0.15)
	6	-1.75 (0.13)	0.01 (0.0)	4.28 (0.31)	0.01 (0.0)	6.26 (0.39)	0.06 (0.0)	347.99 (70.71)	86.22 (9.02)	0.96 (0.10)
25	1	-1.28 (0.17)	0.01 (0.0)	2.78 (0.27)	0.01 (0.0)	4.60 (0.32)	0.06 (0.01)	305.31 (74.63)	77.41 (14.61)	1.11 (0.06)
	2	-1.34 (0.12)	0.01 (0.0)	2.74 (0.19)	0.01 (0.0)	3.78 (0.36)	0.05 (0.01)	437.25 (195.42)	75.03 (14.60)	0.82 (0.04)
	3	-1.25 (0.10)	0.01 (0.0)	2.94 (0.21)	0.01 (0.0)	3.61 (0.33)	0.05 (0.0)	353.73 (134.77)	78.58 (11.44)	0.61 (0.03)
	4	-1.08 (0.14)	0.01 (0.0)	2.18 (0.23)	0.01 (0.0)	6.12 (0.50)	0.08 (0.01)	288.54 (78.60)	81.26 (9.90)	1.80 (0.12)
	5	-0.79 (0.13)	0.01 (0.0)	1.62 (0.14)	0.01 (0.0)	5.07 (0.18)	0.07 (0.01)	231.47 (79.92)	80.94 (21.14)	1.29 (0.09)
	6	-1.24 (0.13)	0.01 (0.0)	2.79 (0.20)	0.01 (0.0)	4.57 (0.42)	0.06 (0.01)	301.48 (92.31)	75.36 (21.02)	1.10 (0.03)

Continued.

Subj	Cond	BF	T BF	F1	TF1	F2	TF2	LRate1	LRate2	TI
26	1	-1.42	0.01	2.50	0.01	6.84	0.05	421.68	214.39	0.95
		(0.42)	(0.0)	(0.59)	(0.0)	(1.19)	(0.01)	(160.86)	(102.21)	(0.15)
	2	-1.35	0.01	2.68	0.01	5.59	0.05	573.56	143.97	0.71
		(0.23)	(0.0)	(0.20)	(0.01)	(0.59)	(0.01)	(464.46)	(33.45)	(0.05)
	3	-1.53	0.01	2.74	0.01	4.65	0.04	418.19	125.09	0.58
		(0.13)	(0.0)	(0.21)	(0.0)	(0.42)	(0.01)	(103.67)	(39.17)	(0.06)
	4	-1.60	0.03	3.80	0.01	6.20	0.07	373.11	98.93	1.10
		(0.55)	(0.04)	(0.25)	(0.0)	(0.77)	(0.01)	(158.93)	(23.17)	(0.07)
	5	-1.52	0.01	2.82	0.01	5.87	0.05	262.98	137.64	0.91
		(0.17)	(0.0)	(0.38)	(0.0)	(0.86)	(0.0)	(29.64)	(38.82)	(0.04)
	6	-1.56	0.01	3.09	0.01	5.91	0.05	464.30	157.67	0.70
		(0.13)	(0.0)	(0.24)	(0.0)	(0.71)	(0.01)	(203.79)	(42.58)	(0.02)

Note: Force units is $N{\bullet}J^{-1}$ Loading Rate units is $N{\bullet}s^{-1}{\bullet}J^{-1}$;values in parenthesis are standard deviation.

Appendix AQ

Female Subject Table Joint Moments

Female subject hip, knee and ankle joint moment data.

			Hip			Knee			Ankle	
Subj	Cond	Ext	Abd	Ext Rotat	Ext	Add	Int Rotat	Plant Flex	Add	Int Rotat
1	1	-0.34	0.16	-0.03	-0.40	-0.11	0.04	-0.32	0.01	0.00
		(0.04)	(0.05)	(0.02)	(0.04)	(0.04)	(0.03)	(0.03)	(0.01)	(0.01)
	2	-0.185	0.37	-0.05	-0.389	-0.10	0.04	-0.28	0.0	0.03
		(0.08)	(0.08)	(0.02)	(0.07)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
	3	-0.43	0.33	-0.05	-0.31	-0.11	0.06	-0.19	-0.02	0.03
		(0.23)	(0.19)	(0.01)	(0.21)	(0.07)	(0.03)	(0.11)	(0.04)	(0.02)
	4	-0.34	0.18	-0.04	-0.37	-0.07	0.02	-0.29	0.01	0.00
		(0.02)	(0.04)	(0.01)	(0.07)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
	5	-0.47	0.12	-0.12	-0.33	-0.08	0.03	-0.27	0.0	0.06
		(0.10)	(0.04)	(0.03)	(0.07)	(0.06)	(0.02)	(0.03)	(0.03)	(0.03)
	6	-0.35	0.23	-0.03	-0.43	-0.07	0.06	-0.22	-0.01	0.05
		(0.11)	(0.15)	(0.02)	(0.14)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)
2	1	-0.93	0.17	-0.12	-0.71	-0.20	0.13	-0.32	-0.03	0.12
		(0.26)	(0.12)	(0.03)	(0.30)	(0.09)	(0.02)	(0.06)	(0.02)	(0.04)
	2	-0.81	0.12	-0.09	-0.61	-0.16	0.10	-0.26	-0.04	0.04
		(0.36)	(0.09)	(0.03)	(0.16)	(0.08)	(0.04)	(0.03)	(0.05)	(0.03)
	3	-0.80	0.12	-0.07	-0.46	-0.10	0.10	-0.21	-0.03	0.05
		(0.13)	(0.05)	(0.02)	(0.14)	(0.04)	(0.06)	(0.05)	(0.02)	(0.04)
	4	-1.05	0.05	-0.11	-0.81	-0.17	0.13	-0.61	0.01	0.07
		(0.19)	(0.11)	(0.08)	(0.04)	(0.03)	(0.06)	(0.10)	(0.01)	(0.05)
	5	-1.23	0.11	-0.09	-0.60	-0.16	0.11	-0.39	0.01	0.04
		(0.30)	(0.11)	(0.02)	(0.05)	(0.04)	(0.02)	(0.09)	(0.01)	(0.04)
	6	-0.89	0.15	-0.14	-0.53	-0.18	0.10	-0.36	-0.01	0.08
		(0.15)	(0.17)	(0.09)	(0.03)	(0.09)	(0.03)	(0.06)	(0.04)	(0.04)
3	1	-0.52	0.08	-0.07	-0.36	-0.06	0.05	-0.38	0.02	0.02
		(0.15)	(0.05)	(0.01)	(0.04)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
	2	-0.60	0.19	-0.08	-0.40	-0.08	0.06	-0.28	0.01	0.04
		(0.32)	(0.07)	(0.02)	(0.08)	(0.01)	(0.01)	(0.05)	(0.01)	(0.01)
	3	-0.72	0.10	-0.07	-0.30	-0.05	0.03	-0.24	0.02	0.02
		(0.16)	(0.06)	(0.02)	(0.14)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)
	4	-0.53	0.06	-0.09	-0.50	-0.06	0.07	-0.49	0.02	0.02
		(0.14)	(0.03)	(0.01)	(0.05)	(0.01)	(0.01)	(0.04)	(0.02)	(0.01)
	5	-0.47	0.07	-0.06	-0.37	-0.05	0.06	-0.34	0.04	0.02
		(0.02)	(0.05)	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)	(0.02)	(0.01)
	6	-0.56	0.08	-0.08	-0.37	-0.07	0.06	-0.32	0.03	0.02
		(0.13)	(0.07)	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)	(0.02)	(0.02)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rotat
4	1	-0.65 (0.23)	0.15 (0.07)	-0.08 (0.02)	-0.60 (0.07)	-0.07 (0.03)	0.07 (0.04)	-0.39 (0.06)	0.02 (0.03)	0.04 (0.02)
	2	-0.49 (0.08)	0.08 (0.05)	-0.07 (0.02)	-0.44 (0.02)	-0.08 (0.02)	0.05 (0.01)	-0.31 (0.04)	-0.02 (0.03)	0.03 (0.02)
	3	-0.80 (0.22)	0.09 (0.03)	-0.06 (0.01)	-0.41 (0.07)	-0.06 (0.01)	0.05 (0.02)	-0.24 (0.03)	-0.02 (0.02)	0.02 (0.02)
	4	-1.34 (0.16)	0.29 (0.11)	-0.18 (0.04)	-0.70 (0.08)	-0.16 (0.04)	0.07 (0.02)	-0.44 (0.07)	0.01 (0.01)	0.07 (0.03)
	5	-0.69 (0.19)	0.15 (0.09)	-0.08 (0.02)	-0.53 (0.04)	-0.09 (0.03)	0.07 (0.02)	-0.33 (0.04)	-0.02 (0.02)	0.04 (0.02)
	6	-0.58 (0.21)	0.12 (0.02)	-0.07 (0.03)	-0.52 (0.11)	-0.07 (0.04)	0.04 (0.01)	-0.32 (0.02)	-0.02 (0.03)	0.02 (0.0)
6	1	-1.38 (0.48)	0.44 (0.13)	-0.21 (0.09)	-0.64 (0.03)	-0.09 (0.03)	0.11 (0.05)	-0.53 (0.05)	-0.07 (0.05)	0.12 (0.03)
	2	-0.91 (0.22)	0.11 (0.06)	-0.07 (0.02)	-0.45 (0.06)	-0.03 (0.02)	0.05 (0.03)	-0.34 (0.04)	-0.09 (0.05)	0.04 (0.04)
	3	-0.97 (0.18)	0.92 (0.10)	-0.25 (0.05)	-0.38 (0.05)	-0.04 (0.03)	0.04 (0.03)	-0.25 (0.08)	-0.03 (0.02)	0.06 (0.03)
	4	-1.99 (0.38)	0.12 (0.03)	-0.03 (0.02)	-0.68 (0.08)	-0.35 (0.32)	0.16 (0.12)	-1.02 (0.28)	-0.36 (0.43)	0.04 (0.03)
	5	-1.04 (0.25)	0.11 (0.04)	-0.04 (0.03)	-0.66 (0.14)	-0.14 (0.21)	0.11 (0.11)	-0.69 (0.07)	-0.24 (0.27)	0.04 (0.01)
	6	-1.28 (0.38)	0.14 (0.10)	-0.09 (0.02)	-0.68 (0.16)	-0.23 (0.23)	0.17 (0.21)	-0.63 (0.08)	-0.33 (0.36)	0.05 (0.02)
7	1	-1.12 (0.15)	0.34 (0.14)	-0.11 (0.04)	-0.57 (0.03)	-0.11 (0.01)	0.03 (0.01)	-0.27 (0.05)	0.01 (0.01)	0.03 (0.01)
	2	-0.67 (0.11)	0.20 (0.04)	-0.11 (0.02)	-0.45 (0.07)	-0.06 (0.01)	0.05 (0.03)	-0.23 (0.02)	0.0 (0.02)	0.04 (0.02)
	3	-1.01 (0.23)	0.29 (0.12)	-0.14 (0.04)	-0.46 (0.17)	-0.09 (0.02)	0.04 (0.03)	-0.16 (0.02)	0.0 (0.01)	0.06 (0.03)
	4	-1.01 (0.13)	0.28 (0.06)	-0.11 (0.04)	-0.60 (0.05)	-0.12 (0.02)	0.06 (0.04)	-0.26 (0.04)	0.0 (0.01)	0.02 (0.01)
	5	-1.07 (0.16)	0.23 (0.12)	-0.12 (0.06)	-0.51 (0.06)	-0.10 (0.02)	0.04 (0.01)	-0.24 (0.02)	0.01 (0.02)	0.04 (0.02)
	6	-0.94 (0.20)	0.24 (0.04)	-0.11 (0.04)	-0.59 (0.23)	-0.09 (0.04)	0.03 (0.02)	-0.21 (0.03)	0.0 (0.04)	0.04 (0.01)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rotat
8	1	-0.73 (0.14)	0.18 (0.12)	-0.04 (0.04)	-0.49 (0.02)	-0.17 (0.02)	0.03 (0.0)	-0.33 (0.05)	0.03 (0.04)	0.03 (0.01)
	2	-0.81 (0.39)	0.16 (0.09)	-0.07 (0.03)	-0.45 (0.02)	-0.16 (0.04)	0.05 (0.01)	-0.24 (0.04)	0.03 (0.02)	0.04 (0.01)
	3	-0.76 (0.22)	0.15 (0.05)	-0.08 (0.06)	-0.44 (0.24)	-0.13 (0.03)	0.05 (0.01)	-0.22 (0.03)	0.01 (0.05)	0.04 (0.02)
	4	-0.66 (0.24)	0.22 (0.09)	-0.06 (0.03)	-0.57 (0.15)	-0.15 (0.03)	0.05 (0.04)	-0.34 (0.05)	0.01 (0.02)	0.05 (0.03)
	5	-0.82 (0.21)	0.12 (0.08)	-0.11 (0.04)	-0.43 (0.08)	-0.18 (0.02)	0.05 (0.02)	-0.32 (0.02)	0.04 (0.02)	0.03 (0.02)
	6	-0.76 (0.28)	0.18 (0.06)	-0.09 (0.05)	-0.43 (0.16)	-0.14 (0.04)	0.03 (0.0)	-0.25 (0.03)	0.03 (0.03)	0.03 (0.03)
9	1	-1.68 (0.45)	0.20 (0.08)	-0.17 (0.08)	-0.47 (0.15)	-0.14 (0.02)	0.12 (0.04)	-0.35 (0.08)	-0.07 (0.08)	0.12 (0.10)
	2	-0.84 (0.28)	0.27 (0.06)	-0.08 (0.03)	-0.35 (0.08)	-0.10 (0.02)	0.05 (0.04)	-0.22 (0.03)	-0.04 (0.02)	0.08 (0.03)
	3	-0.86 (0.23)	0.34 (0.42)	-0.17 (0.17)	-0.41 (0.26)	-0.20 (0.20)	0.11 (0.09)	-0.25 (0.19)	-0.07 (0.17)	0.05 (0.05)
	4	-1.13 (0.24)	0.19 (0.16)	-0.12 (0.02)	-0.45 (0.08)	-0.17 (0.03)	0.10 (0.04)	-0.28 (0.05)	-0.04 (0.03)	0.05 (0.04)
	5	-1.15 (0.30)	0.25 (0.04)	-0.14 (0.03)	-0.36 (0.08)	-0.13 (0.07)	0.06 (0.04)	-0.20 (0.01)	-0.06 (0.04)	0.07 (0.04)
	6	-1.14 (0.29)	0.13 (0.06)	-0.12 (0.05)	-0.26 (0.06)	-0.13 (0.05)	0.04 (0.03)	-0.20 (0.04)	-0.02 (0.03)	0.03 (0.02)
10	1	-0.37 (0.10)	0.06 (0.01)	-0.04 (0.02)	-0.37 (0.02)	-0.03 (0.03)	0.04 (0.02)	-0.37 (0.03)	-0.02 (0.0)	0.02 (0.01)
	2	-0.37 (0.08)	0.13 (0.03)	-0.03 (0.02)	-0.40 (0.07)	-0.04 (0.02)	0.03 (0.02)	-0.31 (0.04)	-0.02 (0.02)	0.03 (0.01)
	3	-0.39 (0.06)	0.12 (0.03)	-0.05 (0.03)	-0.41 (0.11)	-0.07 (0.02)	0.05 (0.02)	-0.26 (0.02)	-0.04 (0.0)	0.02 (0.01)
	4	-0.45 (0.09)	0.11 (0.03)	-0.04 (0.01)	-0.45 (0.03)	-0.04 (0.03)	0.05 (0.02)	-0.46 (0.09)	-0.01 (0.01)	0.02 (0.01)
	5	-0.39 (0.08)	0.13 (0.03)	-0.04 (0.02)	-0.48 (0.13)	-0.02 (0.02)	0.04 (0.02)	-0.35 (0.04)	-0.02 (0.02)	0.03 (0.01)
	6	-0.35 (0.09)	0.14 (0.07)	-0.02 (0.02)	-0.40 (0.10)	-0.02 (0.01)	0.03 (0.02)	-0.29 (0.05)	-0.02 (0.01)	0.02 (0.0)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rotat
11	1	-0.37 (0.06)	0.01 (0.06)	-0.06 (0.02)	-0.45 (0.06)	-0.16 (0.07)	0.06 (0.01)	-0.47 (0.07)	-0.09 (0.04)	0.01 (0.02)
	2	-0.45 (0.13)	0.15 (0.04)	-0.05 (0.02)	-0.39 (0.06)	-0.09 (0.05)	0.05 (0.01)	-0.34 (0.03)	-0.05 (0.01)	0.02 (0.02)
	3	-0.57 (0.11)	0.11 (0.04)	-0.05 (0.02)	-0.39 (0.08)	-0.06 (0.05)	0.04 (0.03)	-0.24 (0.02)	-0.04 (0.04)	0.02 (0.01)
	4	-0.49 (0.13)	0.05 (0.05)	-0.04 (0.03)	-0.50 (0.14)	-0.20 (0.09)	0.12 (0.07)	-0.38 (0.04)	-0.12 (0.07)	0.01 (0.01)
	5	-0.57 (0.13)	0.0 (0.04)	-0.07 (0.02)	-0.55 (0.08)	-0.25 (0.12)	0.14 (0.04)	-0.46 (0.09)	-0.15 (0.10)	0.0 (0.02)
	6	-0.41 (0.04)	0.12 (0.04)	-0.03 (0.01)	-0.40 (0.12)	-0.06 (0.03)	0.04 (0.02)	-0.32 (0.02)	-0.03 (0.01)	0.02 (0.01)
16	1	-0.84 (0.15)	-0.01 (0.01)	-0.16 (0.01)	-0.50 (0.09)	-0.14 (0.05)	0.10 (0.02)	-0.47 (0.04)	0.01 (0.06)	0.03 (0.01)
	2	-0.49 (0.15)	0.06 (0.04)	-0.09 (0.01)	-0.38 (0.15)	-0.06 (0.03)	0.07 (0.03)	-0.28 (0.06)	-0.02 (0.07)	0.02 (0.01)
	3	-0.47 (0.11)	0.08 (0.01)	-0.07 (0.02)	-0.28 (0.16)	-0.06 (0.04)	0.02 (0.01)	-0.24 (0.02)	-0.01 (0.03)	0.02 (0.0)
	4	-0.78 (0.50)	0.01 (0.12)	-0.09 (0.03)	-0.80 (0.14)	-0.26 (0.17)	0.20 (0.13)	-0.52 (0.14)	-0.04 (0.06)	0.0 (0.01)
	5	-0.54 (0.15)	0.06 (0.01)	-0.10 (0.02)	-0.50 (0.01)	-0.03 (0.02)	0.05 (0.01)	-0.53 (0.04)	0.010 (0.02)	0.04 (0.01)
	6	-0.67 (0.05)	0.03 (0.07)	-0.14 (0.03)	-0.53 (0.08)	-0.11 (0.03)	0.09 (0.03)	-0.46 (0.05)	0.04 (0.04)	0.03 (0.01)
20	1	-0.70 (0.06)	0.20 (0.09)	-0.09 (0.04)	-0.50 (0.05)	-0.12 (0.01)	0.04 (0.02)	-0.65 (0.03)	-0.01 (0.03)	0.04 (0.02)
	2	-0.58 (0.08)	0.19 (0.04)	-0.08 (0.03)	-0.53 (0.08)	-0.11 (0.03)	0.04 (0.02)	-0.47 (0.04)	-0.04 (0.05)	0.04 (0.03)
	3	-0.69 (0.16)	0.22 (0.09)	-0.08 (0.02)	-0.49 (0.06)	-0.11 (0.01)	0.05 (0.02)	-0.33 (0.03)	0.00 (0.01)	0.01 (0.01)
	4	-0.50 (0.11)	0.04 (0.03)	-0.06 (0.01)	-0.45 (0.09)	-0.16 (0.01)	0.06 (0.01)	-0.69 (0.14)	-0.01 (0.01)	0.02 (0.01)
	5	-0.62 (0.09)	0.14 (0.10)	-0.07 (0.01)	-0.44 (0.05)	-0.15 (0.02)	0.05 (0.01)	-0.65 (0.07)	-0.02 (0.03)	0.03 (0.03)
	6	-0.70 (0.06)	0.25 (0.10)	-0.09 (0.03)	-0.53 (0.03)	-0.13 (0.02)	0.05 (0.01)	-0.58 (0.03)	-0.02 (0.02)	0.04 (0.03)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rotat
21	1	-0.68	0.23	-0.12	-0.69	-0.10	0.11	-0.39	-0.05	0.07
		(0.32)	(0.10)	(0.03)	(0.07)	(0.04)	(0.03)	(0.15)	(0.02)	(0.05)
	2	-0.71	0.47	-0.14	-0.63	-0.06	0.05	-0.32	-0.02	0.03
		(0.15)	(0.11)	(0.03)	(0.12)	(0.04)	(0.02)	(0.04)	(0.01)	(0.03)
	3	-0.84	0.40	-0.13	-0.59	-0.06	0.04	-0.25	-0.03	0.01
		(0.13)	(0.08)	(0.09)	(0.20)	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)
	4	-0.71	0.30	-0.16	-0.86	-0.09	0.05	-0.73	-0.02	0.02
		(0.28)	(0.17)	(0.04)	(0.42)	(0.07)	(0.02)	(0.44)	(0.01)	(0.01)
	5	-0.56	0.37	-0.13	-0.78	-0.07	0.03	-0.57	-0.02	0.01
		(0.03)	(0.08)	(0.03)	(0.07)	(0.03)	(0.0)	(0.08)	(0.01)	(0.01)
	6	-0.72	0.45	-0.19	-0.76	-0.06	0.07	-0.45	-0.03	0.02
		(0.22)	(0.12)	(0.05)	(0.14)	(0.03)	(0.04)	(0.15)	(0.01)	(0.04)
22	1	-0.64	0.11	-0.09	-0.67	-0.17	0.09	-0.59	-0.04	0.05
		(0.18)	(0.10)	(0.04)	(0.04)	(0.06)	(0.01)	(0.07)	(0.07)	(0.02)
	2	-0.56	0.15	-0.06	-0.54	-0.15	0.07	-0.39	-0.03	0.05
		(0.11)	(0.11)	(0.02)	(0.11)	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)
	3	-0.45	0.09	-0.06	-0.43	-0.07	0.08	-0.26	-0.01	0.05
		(0.06)	(0.11)	(0.02)	(0.07)	(0.03)	(0.02)	(0.02)	(0.01)	(0.04)
	4	-0.56	0.06	-0.08	-0.89	-0.20	0.14	-0.87	0.02	0.07
		(0.20)	(0.08)	(0.05)	(0.02)	(0.09)	(0.05)	(0.06)	(0.06)	(0.08)
	5	-0.63	0.11	-0.12	-0.80	-0.14	0.11	-0.50	0.0	0.07
		(0.17)	(0.09)	(0.07)	(0.08)	(0.03)	(0.03)	(0.07)	(0.02)	(0.05)
	6	-0.66	0.10	-0.13	-0.64	-0.18	0.08	-0.44	-0.07	0.05
		(0.14)	(0.07)	(0.05)	(0.14)	(0.05)	(0.03)	(0.06)	(0.05)	(0.04)
25	1	-0.38	0.37	-0.06	-0.52	-0.08	0.05	-0.41	-0.01	0.02
		(0.03)	(0.21)	(0.02)	(0.04)	(0.01)	(0.02)	(0.02)	(0.03)	(0.0)
	2	-0.37	0.20	-0.10	-0.48	-0.05	0.07	-0.31	-0.03	0.04
		(0.05)	(0.06)	(0.03)	(0.08)	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)
	3	-0.36	0.30	-0.08	-0.43	-0.03	0.04	-0.26	-0.02	0.03
		(0.09)	(0.12)	(0.03)	(0.07)	(0.02)	(0.03)	(0.04)	(0.02)	(0.01)
	4	-0.53	0.28	-0.12	-0.77	-0.08	0.07	-0.56	-0.01	0.04
		(0.08)	(0.05)	(0.0)	(0.02)	(0.03)	(0.02)	(0.05)	(0.01)	(0.02)
	5	-0.39	0.14	-0.08	-0.56	-0.06	0.03	-0.43	-0.01	0.04
		(0.05)	(0.02)	(0.02)	(0.02)	(0.03)	(0.01)	(0.03)	(0.01)	(0.0)
	6	-0.41	0.38	-0.08	-0.49	-0.09	0.08	-0.45	-0.04	0.03
		(0.11)	(0.14)	(0.05)	(0.03)	(0.06)	(0.03)	(0.06)	(0.02)	(0.02)

Continued.

Subj	Cond	Hip Ext	Hip Abd	Hip Ext Rotat	Knee Ext	Knee Add	Knee Int Rotat	Ankle Plant Flex	Ankle Add	Ankle Int Rotat
26	1	-0.76 (0.38)	0.29 (0.13)	-0.14 (0.07)	-0.55 (0.06)	-0.16 (0.04)	0.11 (0.04)	-0.37 (0.11)	-0.03 (0.03)	0.09 (0.05)
	2	-0.54 (0.38)	0.16 (0.13)	-0.08 (0.03)	-0.37 (0.05)	-0.11 (0.02)	0.05 (0.01)	-0.30 (0.04)	-0.02 (0.04)	0.03 (0.02)
	3	-0.39 (0.10)	0.05 (0.07)	-0.04 (0.01)	-0.31 (0.02)	-0.09 (0.03)	0.04 (0.01)	-0.25 (0.03)	-0.01 (0.03)	0.01 (0.01)
	4	-0.62 (0.09)	0.15 (0.13)	-0.10 (0.03)	-0.53 (0.06)	-0.18 (0.03)	0.09 (0.02)	-0.43 (0.10)	0.0 (0.03)	0.02 (0.01)
	5	-0.62 (0.25)	0.20 (0.04)	-0.09 (0.02)	-0.44 (0.04)	-0.10 (0.03)	0.06 (0.03)	-0.33 (0.04)	0.01 (0.05)	0.04 (0.03)
	6	-0.93 (0.30)	0.17 (0.19)	-0.09 (0.03)	-0.52 (0.10)	-0.11 (0.03)	0.06 (0.03)	-0.30 (0.09)	-0.02 (0.03)	0.04 (0.02)

Note: Peak moment unit is $N \cdot m \cdot J^{-1}$; values in parenthesis are standard deviation.

Appendix AR

Female Subject Table Eccentric Joint Work

Female subject hip, knee and ankle joint eccentric work

Subject	Condition	Hip	Knee	Ankle
1	1	-0.13	-0.24	-0.17
		(0.01)	(0.01)	(0.01)
	2	-0.047	-0.265	-0.145
		(0.02)	(0.02)	(0.02)
	3	-0.14	-0.19	-0.09
		(0.14)	(0.12)	(0.06)
	4	-0.08	-0.21	-0.15
		(0.02)	(0.03)	(0.02)
	5	-0.20	-0.20	-0.14
		(0.03)	(0.04)	(0.01)
	6	-0.13	-0.23	-0.10
		(0.01)	(0.02)	(0.01)
2	1	-0.06	-0.17	-0.17
		(0.03)	(0.04)	(0.04)
	2	-0.10	-0.22	-0.12
		(0.02)	(0.02)	(0.03)
	3	-0.12	-0.22	-0.10
		(0.04)	(0.06)	(0.02)
	4	-0.08	-0.14	-0.28
		(0.06)	(0.06)	(0.04)
	5	-0.06	-0.18	-0.16
		(0.01)	(0.02)	(0.03)
	6	-0.08	-0.14	-0.19
		(0.04)	(0.06)	(0.05)
3	1	-0.18	-0.18	-0.18
		(0.03)	(0.02)	(0.01)
	2	-0.29	-0.19	-0.13
		(0.02)	(0.02)	(0.0)
	3	-0.25	-0.17	-0.12
		(0.02)	(0.01)	(0.01)
	4	-0.13	-0.21	-0.22
		(0.02)	(0.02)	(0.01)
	5	-0.27	-0.24	-0.18
		(0.04)	(0.02)	(0.01)
	6	-0.27	-0.21	-0.16
		(0.04)	(0.02)	(0.01)

Continued.

Subject	Condition	Hip	Knee	Ankle
4	1	-0.20 (0.03)	-0.34 (0.07)	-0.22 (0.04)
	2	-0.23 (0.02)	-0.30 (0.04)	-0.18 (0.04)
	3	-0.22 (0.02)	-0.27 (0.03)	-0.14 (0.02)
	4	-0.18 (0.04)	-0.33 (0.05)	-0.13 (0.03)
	5	-0.24 (0.02)	-0.35 (0.03)	-0.18 (0.03)
	6	-0.17 (0.03)	-0.29 (0.03)	-0.19 (0.02)
6	1	-0.10 (0.02)	-0.23 (0.05)	-0.19 (0.02)
	2	-0.04 (0.01)	-0.17 (0.04)	-0.13 (0.03)
	3	-0.10 (0.02)	-0.19 (0.02)	-0.09 (0.02)
	4	-0.12 (0.05)	-0.11 (0.02)	-0.24 (0.06)
	5	-0.07 (0.03)	-0.13 (0.05)	-0.27 (0.02)
	6	-0.08 (0.02)	-0.17 (0.03)	-0.23 (0.03)
7	1	-0.10 (0.03)	-0.35 (0.05)	-0.11 (0.01)
	2	-0.09 (0.01)	-0.30 (0.02)	-0.10 (0.02)
	3	-0.06 (0.02)	-0.26 (0.03)	-0.07 (0.01)
	4	-0.07 (0.01)	-0.32 (0.03)	-0.09 (0.02)
	5	-0.08 (0.03)	-0.31 (0.03)	-0.11 (0.02)
	6	-0.07 (0.03)	-0.30 (0.03)	-0.11 (0.01)

Continued.

Subject	Condition	Hip	Knee	Ankle
8	1	-0.17 (0.06)	-0.31 (0.02)	-0.19 (0.02)
	2	-0.16 (0.04)	-0.25 (0.03)	-0.15 (0.02)
	3	-0.16 (0.03)	-0.21 (0.04)	-0.12 (0.02)
	4	-0.14 (0.02)	-0.30 (0.05)	-0.20 (0.04)
	5	-0.17 (0.04)	-0.25 (0.04)	-0.17 (0.02)
	6	-0.17 (0.01)	-0.21 (0.03)	-0.14 (0.01)
9	1	-0.48 (0.07)	-0.28 (0.06)	-0.10 (0.03)
	2	-0.32 (0.05)	-0.28 (0.05)	-0.09 (0.02)
	3	-0.26 (0.03)	-0.21 (0.05)	-0.12 (0.10)
	4	-0.35 (0.04)	-0.38 (0.08)	-0.11 (0.02)
	5	-0.28 (0.03)	-0.29 (0.05)	-0.09 (0.02)
	6	-0.31 (0.06)	-0.18 (0.04)	-0.09 (0.01)
10	1	-0.05 (0.02)	-0.12 (0.03)	-0.15 (0.02)
	2	-0.14 (0.01)	-0.19 (0.03)	-0.14 (0.03)
	3	-0.16 (0.02)	-0.19 (0.01)	-0.13 (0.01)
	4	-0.06 (0.02)	-0.17 (0.04)	-0.14 (0.02)
	5	-0.10 (0.05)	-0.21 (0.03)	-0.14 (0.02)
	6	-0.12 (0.03)	-0.20 (0.03)	-0.12 (0.01)

Continued.

Subject	Condition	Hip	Knee	Ankle
11	1	-0.03 (0.0)	-0.13 (0.04)	-0.22 (0.01)
	2	-0.04 (0.03)	-0.16 (0.02)	-0.19 (0.02)
	3	-0.08 (0.03)	-0.18 (0.02)	-0.14 (0.01)
	4	-0.02 (0.02)	-0.11 (0.04)	-0.22 (0.04)
	5	-0.06 (0.03)	-0.23 (0.05)	-0.24 (0.03)
	6	-0.04 (0.01)	-0.17 (0.02)	-0.16 (0.01)
16	1	-0.07 (0.03)	-0.22 (0.02)	-0.20 (0.01)
	2	-0.12 (0.02)	-0.14 (0.03)	-0.18 (0.02)
	3	-0.16 (0.01)	-0.14 (0.02)	-0.16 (0.01)
	4	0.0 (0.01)	-0.13 (0.03)	-0.20 (0.04)
	5	-0.05 (0.01)	-0.13 (0.03)	-0.21 (0.02)
	6	-0.05 (0.03)	-0.17 (0.03)	-0.23 (0.03)
20	1	-0.03 (0.01)	-0.09 (0.03)	-0.29 (0.04)
	2	-0.02 (0.01)	-0.18 (0.03)	-0.22 (0.04)
	3	-0.02 (0.01)	-0.21 (0.02)	-0.16 (0.02)
	4	-0.03 (0.01)	-0.02 (0.01)	-0.31 (0.03)
	5	-0.02 (0.01)	-0.06 (0.03)	-0.31 (0.01)
	6	-0.03 (0.01)	-0.16 (0.01)	-0.24 (0.02)

Continued.

Subject	Condition	Hip	Knee	Ankle
21	1	-0.05 (0.12)	-0.48 (0.08)	-0.22 (0.09)
	2	-0.05 (0.03)	-0.33 (0.03)	-0.17 (0.01)
	3	-0.08 (0.02)	-0.29 (0.05)	-0.16 (0.01)
	4	-0.01 (0.04)	-0.26 (0.14)	-0.30 (0.19)
	5	-0.02 (0.02)	-0.26 (0.06)	-0.24 (0.06)
	6	-0.04 (0.02)	-0.36 (0.08)	-0.23 (0.04)
22	1	-0.05 (0.04)	-0.13 (0.05)	-0.27 (0.03)
	2	-0.04 (0.02)	-0.21 (0.06)	-0.20 (0.02)
	3	-0.04 (0.05)	-0.27 (0.02)	-0.13 (0.02)
	4	-0.03 (0.01)	-0.12 (0.02)	-0.26 (0.04)
	5	-0.04 (0.02)	-0.21 (0.05)	-0.25 (0.02)
	6	-0.09 (0.02)	-0.14 (0.05)	-0.26 (0.04)
25	1	-0.05 (0.03)	-0.20 (0.05)	-0.18 (0.04)
	2	-0.17 (0.02)	-0.26 (0.04)	-0.17 (0.02)
	3	-0.14 (0.01)	-0.26 (0.01)	-0.12 (0.01)
	4	-0.02 (0.01)	-0.16 (0.10)	-0.20 (0.02)
	5	-0.07 (0.03)	-0.22 (0.06)	-0.14 (0.02)
	6	-0.10 (0.03)	-0.26 (0.10)	-0.20 (0.06)

Continued.

Subject	Condition	Hip	Knee	Ankle
26	1	-0.05 (0.05)	-0.15 (0.08)	-0.13 (0.03)
	2	-0.05 (0.01)	-0.16 (0.02)	-0.14 (0.01)
	3	-0.14 (0.04)	-0.19 (0.04)	-0.13 (0.02)
	4	-0.03 (0.02)	-0.12 (0.03)	-0.21 (0.03)
	5	-0.05 (0.02)	-0.15 (0.06)	-0.17 (0.02)
	6	-0.10 (0.02)	-0.20 (0.02)	-0.14 (0.04)

Note: Work units is J•PE^{-1};values in parenthesis are standard deviation.

Vita

Kurt Gavin Clowers was born in Lynchburg, Virginia, January 15, 1974. His parents moved to Roanoke, Virginia when Kurt was a small child. He attended Cave Spring High School from 1989-92 and continued his education at Virginia Tech where he received his first bachelor's degree in biology in 1996. From there, he attended The University of Tennessee and obtained his second bachelor's degree in exercise science and became a lifetime member of the Golden Key Society. In December of 2002 he completed his education at The University of Tennessee with a master's degree in human performance and sport studies/biomechanics option. Kurt was married in October of 2002 to Cheryl Lynn Malonee. He completed his Ph.D. in biomechanics, at The University of Tennessee in August of 2005. In the same month he accepted a position with NASA.