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The Acute Effects of Whole-Body Corrective Exercise on Postural Alignment

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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Abstract

The Acute Effects of Whole-Body Corrective Exercise on Postural Alignment

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Master of Science

This study examined the acute effects of whole-body corrective exercise on postural alignment in a sample of 50 male participants (18-30 y) displaying asymmetrical postural deviations. All participants were randomly assigned to either a nonexercise control ($n = 25$) or corrective exercise treatment ($n = 25$) group. A three-dimensional motion analysis Vicon system was employed to quantify standing postural alignment at the beginning and end of a 6 d study. Postural misalignments were determined in degrees of symmetry (tilt) and rotation using horizontal and vertical virtual plumb lines for the following locations: hip (ASIS), leg (greater trochanter), shoulder (acromion process), and head (ear). The treatment group completed five corrective exercise sessions on separate days which included 11 exercises (requiring about 60 min per session to complete). The control group performed no intervention and maintained a normal lifestyle. At the commencement of the study there were no significant differences in the degree of postural misalignment between the control and treatment groups at any of the postural measurements. At the conclusion of the treatment period (following the five sessions of corrective exercise), there were no significant differences in any of the postural alignments of any of the postural measurements between the treatment and control groups. For example, all of the following postural measurements were not significantly different (critical $F \geq 4.24; df = 1,25$) between groups: hip (ASIS) tilt ($F = 0.05$), hip (ASIS) rotation ($F = 0.15$), greater trochanter tilt ($F = 1.58$), greater trochanter rotation ($F = 0.33$), shoulder tilt ($F = 2.63$), shoulder rotation ($F = 0.07$), head tilt ($F = 2.39$), and head rotation ($F = 2.79$). The results of this study suggest that five sessions of corrective exercise were insufficient to significantly improve standing postural alignment. In addition, this study appears to be the first to document whole-body postural alignment using 3D video analysis.

Keywords: functional exercise, postural misalignment, 3D motion analysis

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Table of Contents

Title Page	i
Abstract	ii
Acknowledgements	iii
Table of Contents	iv
List of Tables	v
Table 1. Changes in postural deviations	16
Table 2. F-values of the control versus treatment groups	17
List of Figures	vi
Figure 1. Marker placement	18
Figure 2. Example of angle calculations	19
Introduction	1
Methods	4
<i>Participants & Pre-screening</i>	4
<i>Procedures</i>	5
<i>Angle Calculations</i>	8
<i>Data Analysis</i>	9
Results	9
Discussion	10
References	14
Appendix A	20
Appendix B	21

List of Tables

Tables

1. Means and standard deviations of changes in postural deviations.....16
2. Control vs. treatment comparisons.....17

List of Figures

Figures

1. Marker placement	18
2. Example of anatomical landmarks for angle calculations	19

Introduction

Corrective exercise is commonly employed in physical therapy, chiropractic therapy, and athletic training to rehabilitate musculoskeletal injuries, improve postural alignment, and restore functional fitness.[1, 2] In addition to clinical therapy, nonsupervised home exercise programs are an integral part of standard rehabilitation, helping to ensure that the necessary stimulus for optimal improvement is achieved.[3] Because of the potential benefits and overall effectiveness of corrective exercise in both healthy and injured populations, a variety of nonmedical professionals (in pain-free centers, fitness facilities, etc.) are assisting healthy clients with corrective exercise routines to improve postural alignment and minimize musculoskeletal pain. In addition, exercise professionals often work under the direction of a medical professional in helping injured clients perform medically prescribed corrective exercise programs.[3]

Corrective exercises are targeted to improve the neuromuscular system and enhance one's functional movement.[4] Mills et al.[5] defines functional movement as the "ability to exhibit proper levels of musculoskeletal mobility and stability throughout the body while completing fundamental movement patterns with accuracy and efficiency." Corrective exercises are specifically designed to improve the proper activation and relaxation of local stabilization muscles (typically positioned in close proximity of a given joint). A secondary purpose is to improve the proper activation and relaxation of the global, movement oriented muscles. (Typically longer in length and spanning single or multiple joints.)[6] The training effect of corrective exercise routines result in proper neuromuscular control leading to optimal arthrokinetic and osteokinetic movement patterns,[6] postural alignment, overall movement efficiency, and proper healing of injured tissues.[6]

When the local and global muscles fail to activate or relax at the appropriate time or attain an appropriate tension level, it is often described as “neuromuscular dysfunction” or “muscle imbalance”.[6] Muscle imbalances normally lead to arthrokinetic and osteokinetic dysfunction.[7] Studies suggest that muscle imbalances stem from improper sitting and standing postures,[6, 8] repetitive movements with a misaligned posture,[1, 8] or from a musculoskeletal injury and related pain.[1,6,8-12] Corrective exercise routines have been shown to improve muscle imbalance by properly activating the local and global muscles (via proper neuromuscular control), thereby improving postural alignment across various segments of the body.[1,2,6-8,10,13,14] For example, McDonnell et al. reported significant acute changes in the postural alignment of the neck and a reduction in headaches following corrective exercise and proper postural positioning.[7] Similarly, Kuo et al. found improvements in thoracic posture following a 10-week Pilates based exercise program.[15] Various studies have also examined the influence of corrective exercise on improving alignment of the lower back as a means of alleviating lower back pain.[1,2,10,12,15] A study by Kumar et al.[1], for example, compared the effects of conventional (ultrasound and shortwave diathermy) treatment to dynamic muscular stabilization exercises. Following a 35-day treatment period, the corrective exercise group experienced a greater decrease in lower back pain than the conventional treatment.[1] Sahrmann and others [6,11] suggest that an ideal postural alignment helps to decrease strain on the musculoskeletal system, minimize microtrauma to the muscles and joints, and thereby decrease both acute and chronic musculoskeletal pain and discomfort. Although found to be effective in practice, there is little research that has objectively documented the effects of whole-body corrective exercises on postural alignment.

There are many corrective exercises promoted through both medical- and nonmedical-based programs. In the early 1970s, a nonmedical corrective exercise program was developed by Pete Egoscue. The overarching purpose of the Egoscue corrective exercise program is to improve postural alignment and minimize musculoskeletal pain using a personalized menu of corrective exercises based on a standing postural assessment.[9] Typically, a trained Egoscue corrective exercise specialist evaluates the standing posture of the participant from the anterior, posterior, lateral left and right-side views. Following this evaluation, the participant is classified into one of three primary conditions: Condition 1 (displaying an anterior pelvic tilt), Condition 2 (displaying body rotation or asymmetry), and Condition 3 (displaying a posterior pelvic tilt). Based on this classification, an individualized corrective exercise menu is generated using Egoscue computer software. A typical corrective exercise menu normally consists of 10-20 different exercises and may take 45-75 min to complete. To date, the treatment effect of the Egoscue method has not been documented or evaluated using a controlled study, although it appears to be of benefit for those with musculoskeletal misalignments or musculoskeletal pain based on client testimonials.[4,9]

Three-dimensional (3D) video motion analysis is considered the criterion measure for quantifying and describing human movement patterns.[16-19] For example, the Vicon 3D video motion capture system recently demonstrated a test-retest accuracy of $63 \pm 5 \mu\text{m}$. [20] Currently, various 3D video capture systems are available for use in the research and clinical setting.[16,18,19,21] Many research studies have employed 3D imaging to evaluate a variety of movement patterns.[10,16,17,22] In contrast, it appears that only one study [22] has used 3D imaging for static posture analysis. Ferreira et al. utilized 3D analysis to evaluate the standing postural alignment of 115 college-age participants. Their findings suggest that 3D analysis can

accurately quantify a “normal posture” (in the anterior, posterior, and lateral views). However, the Ferreira et al. study was descriptive in nature, and did not employ a corrective exercise intervention, or monitor changes in standing posture across a treatment period. Recently, researchers have recommended that 3D imaging be utilized to document the effectiveness of corrective exercises in improving standing posture.[22]

Several studies have documented the chronic effects of corrective exercise on postural alignment.[1,2,7,10,14,15] However, there appears to be no published research on the acute effects of corrective exercise and whether or not it can improve standing postural alignment.[13] In addition, no published research could be found documenting acute changes in postural alignment using 3D motion analysis. Therefore, the primary aim of this study was to determine whether or not an acute 5d corrective exercise routine can significantly improve postural alignment (as measured with 3D analysis).

Methods

Participants & Pre-screening

Potential participants were recruited at the university using campus flyers, email announcements, and social media. To qualify, participants had to be male, in good health, between the ages of 18 and 30 y. Participants also had to be capable of performing normal physical activities, which was determined based on completion of the Oswestry Disability Index (ODI) and Physical Activity Readiness questionnaire (PAR-Q). The ODI is a simple ten-item questionnaire that requires participants to indicate which activities of daily living can be performed without musculoskeletal pain.[23] The PAR-Q is a brief questionnaire used to ascertain whether or not medical approval is necessary before participation in physical activity.[24] Participants also had to be classified as having postural asymmetry or rotation

(Condition 2) as per the Egoscue classification system [4] based on a standing postural assessment. Finally, participants were excluded from the study if they: 1) experienced any type of joint injury over the previous six months; 2) were currently participating in any form of corrective exercise or physical therapy; 3) were currently taking any type of medication for the treatment of disease; or 4) were suffering from any type of chronic joint pain.

Participants were notified immediately, whether or not they met the inclusion criteria for the study. Once invited to participate, each participant was asked to complete a written informed consent document and complete a brief pre-participation questionnaire. After this, each participant's body mass and height was measured to the nearest 0.1 kg and height to the nearest 0.5 cm (with participant wearing no shoes) using a balance beam scale and a stadiometer (OHAUS, Parsippany, NJ), respectively. All participants were then randomly assigned to one of two equally-sized groups: a treatment group and a control group (based on a randomized controlled experimental design). To do this, participants selected a paper slip from a bag containing 50 paper slips (25 labeled for the control group and 25 for the treatment group). No paper slips were returned to the bag after being drawn.

A total of 51 potential participants were pre-screened, with only one participant unable to qualify due to musculoskeletal pain. All other potential participants had some degree of postural asymmetry or rotation (Condition 2). Upon successful completion of the study, participants were given a nominal payment (\$30 for those in the control group and \$40 for those in the treatment group) based on their overall time commitment.

Procedures

Following the pre-screening session, qualifying participants (n = 50 males; Table 1) were invited to return to the Human Performance Research Center (HPRC) the next day for additional

testing. All study methods and procedures were approved by the university's Institutional Review Board for the use of Human Subjects before data collection.

Day 1. Upon arriving at the HPRC, participants were asked to change into compression shorts with no shirt, stockings, or shoes. Participants were then fitted with 16 retro reflective markers, that were adhered to the skin at the following anatomical landmarks: left and right acromion process (AP), left and right anterior superior iliac spine (ASIS), left and right greater trochanter at the hip (gtrochanter), medial and lateral sides of both knees, left and right lateral and medial malleolus and in front of the left and right ear (see Figure 1). A circular Velcro base was adhered to the skin at the exact anatomical landmark, and then a reflective marker was attached to each Velcro base. Once the reflective markers were in place, a circle was drawn around each Velcro base using a hospital "skin marker" to help ensure the consistent replacement of each Velcro base and reflective marker across each day of the study. The same test administrator placed and replaced all reflective markers during the test week. Between test days, participants were also asked to retrace the circles drawn on their skin (at home) using a skin marker to ensure continued visibility of each circle.

Once the participant had all 16 reflective markers properly positioned, he was asked to stand relaxed for 5 s while 10 Vicon cameras (including six MX13+, two F20, and two T20 cameras; positioned around an 8-meter circle) recorded the position of the reflective markers at a rate of 60 Hz.[18] The participants walked around the room and returned to the original standing position. This was repeated twice to get three trials. Following this assessment, a test administrator removed all 16 reflective markers from the skin.

Treatment Group

After the initial postural assessment, participants in the treatment group were asked to complete a corrective exercise routine (designed for Condition 2, from a printout using the Egoscue software; Egoscue, San Diego, CA). The exercise routine included 11 corrective exercises and required approximately 60 min to complete. All participants in the treatment group performed the same exercise routine. A trained test administrator instructed participants on how to perform each corrective exercise, supervised the actual performance of each exercise, and provided any necessary cues and verbal feedback to ensure that each exercise was done correctly. Upon completing the corrective exercise routine, the 16 reflective markers were carefully replaced on the previously drawn circles at each anatomical landmark and the participant was asked to stand relaxed for 5 s while the Vicon cameras recorded the current standing posture. The participants walked around the room and returned to the original standing position. This was repeated twice to get three trials. Following this assessment, a test administrator removed all 16 reflective markers from the skin.

Control Group

After the initial postural assessment, participants in the control group were instructed to sit quietly in a chair for 60 min. During this time, participants were permitted to read, study any materials of their choice, or use a computer. Immediately following this rest period, the 16 reflective markers were carefully replaced on the previously drawn circles at each anatomical landmark and the participant was asked to stand relaxed for 5 s while the Vicon cameras recorded the standing posture. The participants walked around the room and returned to the original standing position. This was repeated twice to get 3 trials. Following this assessment, a test administrator removed all 16 reflective markers from the skin.

Day 2. Participants in the treatment group came to the HPRC to complete the same 60 min corrective exercise session with supervision. Participants in the control group were instructed to maintain their normal daily routine throughout the study. All participants were reminded to retrace the 16 circles on their skin, as needed.

Days 3 and 4. Participants in the treatment group were instructed to complete the same 60-min corrective exercise routine at home on Day 3 and Day 4. Participants in the control group were instructed to maintain their normal daily routine. All participants were reminded to retrace the 16 circles on their skin, as needed.

Day 5. All participants returned to the HPRC on the fifth day of the study. Participants in the treatment group were asked to complete the same supervised 60 min corrective exercise routine, whereas participants in the control group were asked to sit quietly for 60 min. After completing the respective treatment or control group activity, the 16 reflective markers were placed on each anatomical landmark (circle) with the participant dressed the same as they were on Day 1. As before, the participant was asked to stand relaxed for 5 s while the Vicon cameras recorded his standing posture. Following this assessment, all 16 reflective markers were removed from the skin.

Angle Calculations

The Vicon system gathers data in the form of coordinate points (X,Y,Z). Data from each of the three trials of each postural assessment were summed and averaged to obtain a single value of each session. Angles in the frontal plane (Z) were calculated by creating a straight line projected medially from the right side of each set of markers to the left side marker (greater trochanter, shoulder, knee, and ear) looking for asymmetry. To calculate rotation in the transverse plane (Y) a virtual left side marker was created with the same Z and X coordinates as

the right side markers. Another line was created from right marker projected medially (greater trochanter, shoulder, knee, and ear) to a virtual left marker created with the same Y coordinate and compared to the actual line between markers at each segment (see Figure 2).

Data Analysis

Pre- and post-exercise standing angles of alignment (represented by angles relative to the horizontal and vertical) at each joint were compared between the treatment and control groups to the nearest degree. The R statistical software system was used to perform the statistical analyses [25] across Day 1 (pre-test) to Day 1 (post-test) as well as Day 1 (pre-test) to Day 5 (post-test). The analyses were completed using a mixed linear model as implemented using the “lmer” command in R. This approach appropriately accounts for individual variation as well as random error. The degrees of freedom were chosen to be conservative. A critical F of 4.24 ($df = 1,25$) was employed to determine significance at the (nominal) $p < 0.05$ level in all cases. The intercepts indicated the pre-test (starting) postural alignment scores for both control and treatment groups; while the slopes included changes from the pre-test (starting) postural alignment scores to post-test postural alignment scores when comparing control and treatment group data. Thus, a significant difference in slope indicated a possible treatment effect.

Results

All 50 male participants (mean \pm SD; 23.3 ± 2.3 years of age, 83.6 ± 14.0 kg body mass, and 180.3 ± 7.9 cm body height) successfully completed the requirements of this study. The treatment group ($n = 25$) self-reported 100% compliance in completing the two at-home corrective exercise sessions (Days 3 and 4). The pre- and post-test postural deviations (in degrees) for the control and treatment groups are outlined in Table 1. Based on analysis of the intercepts, the starting postural alignment values for the control and treatment groups were not

significantly different at any location. When evaluating any change in postural alignment between the control versus treatment group (from the analyses of slopes; Day 1 pre-test to Day 1 post-test), only the hip symmetry measurement was shown to be significantly different following a single session of corrective exercise; however, this significant difference was due to changes in hip symmetry in the control group, not the treatment group (see Table 2). On the other hand, no significant differences in postural alignment scores were found when evaluating slopes across the 5 d treatment period (Day 1 pre-test to Day 5 post-test; see Table 2).

Discussion

This study appears to be the first to examine the acute and short-term effects of whole body corrective exercise on postural alignment. It also appears to be the first study to use 3D video capture analysis to evaluate changes in standing postural alignment following acute corrective exercise. Consequently, this investigation provides additional information and methodologies to more fully and accurately document the influence of corrective exercise on postural alignment.

The present study involving a short-term program of corrective exercise did not demonstrate a statistically significant treatment effect in improving the standing postural alignment in a sample of adult males with postural deviations. This finding was not surprising due to the acute nature of the study, which provided only five 1 h sessions of corrective exercise. In contrast, longer-term studies (8-12 weeks) have shown statistically significant improvements in static posture.[1,2,7,10,14,15] For example, Harman reported a statistically significant improvement in mean forward head posture in a sample of 40 adults (with an initial forward head lean of 24 to 25 degrees) following a 10 week at-home corrective exercise program.[14] Likewise, Kuo reported significant improvements in spinal posture following a 10 week Pilates

program.[15] However, despite the evidence and logic for conducting a longer-term study, we elected to perform a short-term study to document the influence of short-term corrective exercise treatments using 3D video capture analysis.

There may be various reasons why the current study did not elicit a significant treatment effect. First, the short-term nature of this study may have not allowed enough time for the treatment effect to demonstrate a change. A longer treatment period (similar to previous studies) may have generated a treatment effect.[1,2,7,10,14,15] Second, although all of the participants in this study had some degree of postural misalignment (categorized in the Egoscue method as Condition 2)[9], none of the participants reported pain and none were performing corrective exercises or under the care of a physical therapists. Thus, the postural misalignments observed in this group of subjects were not severe enough to cause complaints and may have not been severe enough to see noticeable improvements with corrective exercise. The inclusion of participants with more severe misalignments and accompanying musculoskeletal pain may have resulted in measureable improvements in postural alignment over a 5-day period. Third, all people exhibit some degree of static postural sway (movement deviation) while standing.[10,22] Perhaps this inherent postural sway variability that occurs naturally while standing added to the within-participant error (and diluted the magnitude of the F-ratio calculations). Fourth, although 3D video capture analysis is considered a criterion measure in movement science, it still exhibits a small degree of random measurement error as noted in previous research.[20,22]

The strengths of the current investigation includes the use of a randomized control design which allowed the treatment and control groups to begin with no significant difference in initial postural scores. A fairly large sample size was also employed which increased our statistical power, thus increasing the likelihood of identifying a significant improvement in postural scores

(if a positive treatment effect did actually exist). Participants were prescreened to ensure that our sample met a given standard of control. Valid and reliable equipment was employed to assess changes in postural alignment. Participants in the treatment group were instructed on how to complete the corrective exercises and were supervised by an exercise specialist on three of the five exercise days. The corrective exercises were also easy to perform and required approximately 1 h to complete, ensuring a typical acute musculoskeletal stimulus. In the end, all participants complied fully with all study requirements.

The limitations of this study include the use of only college-aged males, thus our results are not generalizable to other individuals. Only male participants were included in this study to allow for an accurate placement of anatomical markers when shirts were not worn. The placement and removal of the reflective markers may have contributed to possible measurement error; however, the reference circle drawn around each reflective marker provided a constant replacement location throughout data collection. Error in marker placement during Day 1 and Day 5 was minimized by having a single test administrator place and replace each marker. All participants had some degree of postural deviation (body rotation or asymmetry), but in hindsight it would have been better to initially document the degree of deviation and then recruit only those with moderate to extreme postural deviations. Our study was intentionally designed as a preliminary acute, short-term study; therefore our results are not representative of the effect of long-term chronic corrective exercise on posture. Finally, we only assessed postural deviation and did not measure changes in musculoskeletal pain, joint mobility, joint stability, or functional movement across the acute treatment period.

Future research is warranted to further examine the role of corrective exercise in improving postural alignment and functional movement. For example, it would be beneficial to

continue to gather evidence on the specific dose or stimulus required to exert a positive effect on postural alignment and function (based on the duration of exercise session, frequency of exercise session, and overall length of the exercise program). In addition, the influence of various covariates (such as age, gender, degree or severity of postural deviation, level of pain, etc.) should be explored. Documenting typical participant adherence rates in corrective exercise programs could also be of interest, along with developing behavior change strategies for improving motivation, overcoming barriers, and preventing relapse. Additional research is also needed to further explain how much and to what extent corrective exercise can minimize musculoskeletal pain, improve functional movement patterns, and enhance activities of daily living.

In conclusion, although our results did not generate a statistically significant treatment effect in healthy male adults, this study begins the scientific process of expanding our understanding of corrective exercise on standing postural alignment. Specific methods for assessing and calculating standing postural alignment data using 3D analysis were outlined. Additional study is needed to fully document the influence of short- and long-term corrective exercise on improving postural alignment and functional movement, preventing musculoskeletal injury, and minimizing musculoskeletal pain across various populations.

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Table 1. Changes in postural deviations (mean \pm SD; in degrees) from Day 1 to Day 5 for the control (n = 25) and treatment (n = 25) groups

	Pre-test (Day 1)		Post-test (Day 5)	
	Control	Treatment	Control	Treatment
Hip (ASIS) symmetry (θ)	1.2 \pm 1.1	1.7 \pm 1.1	1.4 \pm 1.1	1.8 \pm 1.6
Hip (ASIS) rotation (θ)	2.0 \pm 1.3	1.9 \pm 1.7	2.0 \pm 1.5	2.1 \pm 1.6
Leg (gtrochanter) symmetry (θ)	2.0 \pm 1.4	1.8 \pm 1.6	1.7 \pm 1.4	2.0 \pm 1.3
Leg (gtrochanter) rotation (θ)	3.0 \pm 2.2	2.9 \pm 2.4	2.4 \pm 2.2	2.8 \pm 1.8
Shoulder (AP) symmetry (θ)	1.6 \pm 1.2	1.2 \pm 0.9	1.6 \pm 1.2	1.6 \pm 1.3
Shoulder (AP) rotation (θ)	2.5 \pm 1.6	1.7 \pm 1.6	1.9 \pm 1.4	2.0 \pm 1.3
Head (ear) symmetry (θ)	2.0 \pm 1.6	1.3 \pm 1.0	2.0 \pm 1.5	2.0 \pm 1.8
Head (ear) rotation (θ)	1.6 \pm 1.7	3.8 \pm 4.8	2.3 \pm 1.7	1.7 \pm 1.2

θ = mean degree of postural deviation

Table 2. F-values of the control versus treatment groups (using slope comparisons) for each postural alignment measurement (pre-test, Day 1 to post-test Day 5; n = 50).

Postural Alignment Measurement								
	Hip (ASIS) symmetry	Hip (ASIS) rotation	Leg (gtrochanter) symmetry	Leg (gtrochanter) rotation	Head (ear) symmetry	Head (ear) rotation	Shoulder (AP) symmetry	Shoulder (AP) rotation
T1	8.49*	0.02	0.11	3.14	0.16	1.42	0.13	0.15
T2	0.05	0.15	1.58	0.33	2.39	2.79	2.63	0.07

T1 = Pre-treatment (Day 1) vs Post-treatment (Day 1)

T2 = Pre-treatment (Day 1) vs Post-treatment (Day 5)

Note: A critical F of 4.24 (df = 1,25) was employed to determine significance at the (nominal) .05 level in all cases.

*Only one of the postural alignment measurements reached a critical F-value of 4.24.

Figure



Figure 1. Marker placement



Figure 2. Example of angle calculations

Appendix A

ID#: _____

Group: _____

Participant Information

Human Performance Research Center

Investigator: Nicole Rencher

Brigham Young University

Name: _____

Phone Number: _____

Email: _____

Age: _____ Gender: Male / Female

Race: _____

Body weight: _____ lbs Height: _____ feet/inches

Is the participant currently taking medications to minimize muscle/joint pain: Yes / No

If "Yes", please list the name and amount taken each day (on average):

Is the participant currently under the care of a physical therapist or chiropractor: Yes / No

NOTE: Inform the participant to please use the restroom **before** performing any research in the lab. (Once data collection begins, the participant should not use the restroom at any time.)

Appendix B

Standing Posture Assessment

Name: _____ Date: _____

Front View

Back View

Top View

Side Views

R

L

L

R

R

L

L

R

