DYNAMIC BALANCE

OF EXPERIENCED AND NOVICE CLIMBERS

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Abstract

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Climbing requires heavy use of the upper body muscles in the torso and arms to pull the body vertically or traverse horizontally. The upper body profile of climbers has been characterized, however there is little research that has examined the lower body and its contribution to climbing performance. There are studies that have examined postural control while climbing, but no study has evaluated the dynamic balance of the lower extremities in climbers. For this study, lower body dynamic balance was measured using normalized reach distances of the Star Excursion Balance Test (SEBT). Eighteen adult, indoor climbers (n=12) and non-climbers (n=6) participated in this study. Climbers were designated either Experienced (n=7) or Novice (n=5) based on their reported redpoint ability. Experienced climbers had significantly greater reaches than Novices for the POSTM and MED excursions (p=.045, .002), and significantly greater reaches than Controls for COMP, POST, POSTM, and MED excursions (p=.022, .014, .018, P<.0001). We observed symmetry-differences between limbs in SEBT reaches as well. Experienced climbers had smaller symmetry-differences compared to Novices for the POSTM direction (p=.023), and in the POSTL and ANTM excursions compared to Controls (p=.027, .011). Novices had smaller symmetry-differences compared to

Experienced climbers for COMP and ANTL scores (p=.044, .021). The purpose of this study was to determine lower body dynamic balance in rock climbers with different ability levels. Results of this study partially supported the alternate hypothesis in that Experienced climbers had greater distance in reaches of the SEBT compared to Novices, but only in the POSTM and MED directions.

Table of Contents

List of Tables

List of Appendices

Chapter 1: Introduction

Rock climbing has soared in popularity in recent years. In light of the growing number of climbers, there is still a lack of data on how to properly train athletes who are preparing for competition. The trend for climbing research is to look at the anthropometric measurements, or upper body strength and relate those variables to the climber's best route ascended (Draper et al., 2011; Balas et al., 2012). The upper body characteristics of a climber are well understood, with great recommendations on how to improve the strength, endurance, and power of the upper body (Phillips et al., 2012; Michailov, 2014), but no mention in the literature of any lower body exercises.

The classic model of an elite climber is one that is small in stature, low body fat, high ratio of strength to body mass, and sometimes an increased arm span relative to height (Watts et al., 2004; Laffaye et al., 2014). Climbers have great endurance for the upper body in tests of timed bent-arm hang, and number of pull-ups and curl-ups, with elite climbers scoring significantly better than novices or non-climbers (Grant et al., 1996 & 2001; Mermier et al., 2000; Balas et al., 2012). Upper body power and finger rate of force development is important is climbing as well. In a vertical arm-jump test from a pull-up, more experienced climbers reached higher (Laffaye et al., 2014 & 2015) and also reach full grip strength faster than controls (Balas et al., 2012). These attributes contribute to climbing performance since it requires being able to quickly reach a small hold and having the strength to maintain positioning.

Quaine et al. (1997) measured forces going through a handhold to examine postural control. When releasing the right hand from a quadrupedal position, the vertical forces going through the left handhold increased to oppose the release of the other limb and stay stable. However, when the size of the handhold decreases, so do the vertical and horizontal forces going through it (Fuss et al., 2013). Fuss et al. (2013) made an adjustable hold with added panels to increase the angle and slope of the hold. After the hold decreased to its smallest sizes, force vectors showed that a climber began pushing into the hold, rather than pulling down, to lift the body vertically (Fuss et al., 2013). If a climber is pushing into the hold with the hand, then movement and stabilization are influenced by the feet and legs. However, in relation to lower body parameters, the profile of a rock climber is not well understood.

Studies that have measured lower body parameters have typically found little to no association with climbing performance (Grant et al., 1996; Mermier et al., 2000; Grant et al., 2001; Espana-Romero et al., 2009). Regarding flexibility, only leg-span has been found to be significantly greater in elite male climbers compared to novices and non-climbers (Grant et al., 1996; Draper et al., 2009). Dynamic flexibility seems to discern ability levels better than a single range of motion (Draper et al., 2009). In a variant of a vertical foot-raise test (lifting the toe up a wall with a bent knee and measuring the distance) elite climbers had higher reaches than novice and intermediate climbers (Draper et al., 2009). Lower body power, like flexibility, is shown to have little to no association with climbing performance or climbing time to exhaustion (Mermier et al., 2000; Espana-Romero et al., 2009). Espana-Romero et al. (2009) measured squat jumps between climbers of different skill levels, however, the highest jump was a mere 34.1cm (~13.4in). With such low jumps, dynamic balance may be more of a contributor to climbing ability.

There is a small body of research that suggests the importance of lower body dynamic balance when ascending a wall (Quaine et al., 1997; Quaine & Martin, 1999; Noe, 2006; Zampagni et al., 2011; Russell et al., 2012). Dynamic balance refers to maintaining balance (base of support) during functional tasks (Gribble & Hertel, 2003). During climbing, a climber's feet are often not level and may be resting on holds that protrude enough for only the toes to be touching. While ascending a vertical wall, experienced climbers showed more dynamic movement and oscillation of their center of mass in contrast to non-climbers (Zampagni et al., 2011; Russell et al., 2012). Experienced climbers transferred most of their weight onto one foot before lifting the other foot to the next hold. In contrast, the controls moved more rigidly, showing less shifting of their weight and distributed their mass evenly between their feet (Zampagni et al., 2011; Russell et al., 2012). The center of mass of climbers was further from wall with less elbow flexion than controls, allowing more controlled movement and the biceps brachii muscle to be at a more optimal functional length (Russell et al., 2012). This evidence shows that climbers maintain movement patterns to minimize fatigue and maximize efficiency for climbing longer periods of time (Sibella et al., 2007; Zampagni et al., 2011; Russell et al., 2012). This efficiency may indicate the importance of having dynamic balance of the lower body in climbing. Having effective movement while climbing route would require not only strength of the feet and legs, but excellent proprioception to move fluidly (Quaine et al., 1997). Given this, one would postulate that more experienced climbers, with the ability to climb more difficult routes, would most likely have better lower body dynamic balance than novices.

No prior study has quantified the lower body dynamic balance of experienced climbers compared to novice climbers. Compared to resistance training, a regimen of climbing was shown to improve subjects' balance, but this was only measured statically on a beam (Gallotta et al., 2015). Without the use of expensive equipment for motion capturing, there are many simple tests that can quantify dynamic balance. The Star Excursion Balance Test (SEBT) is a basic assessment that requires few resources and could possibly be applied to climbers.

Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is used as a simple tool for quantifying lower body dynamic balance. For the SEBT, tape is laid down on the ground to form the shape of an asterisk. The test subject places one of his/her feet in the middle of the asterisk, then keeping that foot in the same position, reach with the opposite foot along all eight lines to extend the big toe as far as possible. In theory, the better the postural control, the farther one's leg reach will be in all directions (Kinzey & Armstrong, 1998). Some studies have modified the SEBT to use only three or four directions instead of all eight, and all of those studies have shown a high degree of reliability (Kinzey & Armstrong, 1998; Olmsted et al., 2002: Gribble et al., 2013; Hyong & Kim, 2014; Lieshout et al., 2016).

The SEBT has been typically used as a measure for identifying those with ankle instability (Olmsted et al., 2002; Gribble et al., 2004). The SEBT has also been shown to discern an individual's athletic status. In other more common sports such as football, soccer, and dancing, athletes who compete at higher levels have displayed greater dynamic balance than novice athletes and controls (Thorpe & Ebersole et al., 2008; Ambegoankar et al., 2013; McCann et al., 2015; Palmer et al., 2015). With the exception of Palmer et al. (2015), these results were quantified using the SEBT. Therefore, the SEBT was chosen as a measuring tool is this study.

Although rock-climbing is a sport with different physical requirements than sports like soccer or basketball, maybe the trend of more experienced athletes scoring better SEBT results would be true for climbers as well. It is possible that climbers who can scale harder routes would have better dynamic balance than those who climb easier routes.

Purpose of the Study

The purpose of this study was to quantify the lower body dynamic balance of adult rock climbers of two different skill levels and evaluate whether differences in normalized reaches existed between skill levels and controls (non-climbers). Both left and right legs were measured for flexibility and balance in order to quantify symmetry, and assess whether the less experienced climbers and non-climbers had greater differences between limbs than experienced climbers.

Primary Hypothesis.

1. Climbers that have better climbing ability will score better in the SEBT and have similar scores between limbs compared to those who have lesser climbing ability and controls.

Secondary Hypotheses.

1. Both experienced and novice climbers will score similarly in average reach distances for the right and left sides.
2. Climbers with a greater level of ability will have greater flexibility in the hips and ankle, in terms of range of motion within the joints compared to the control subjects or climbers with lower level of ability.

Chapter 2: Methods

Subjects

All climber subjects were recruited through word of mouth or surveyed in person from the general HSU student population, the HSU climbing club and the local Far North Climbing gym in Arcata, California. Control subjects were recruited on campus from a beginner's weight-lifting class. Prior to participation, subject candidates were screened for inclusion criteria (see Screening form-appendix B). Inclusion criteria include 1) no major neurological or orthopedic injury to in past six months, 2) no current major or minor neurological or orthopedic injury in lower extremities and 3) age between 18-35 years. Subjects were excluded if they had a history of back, hip, or lower extremity injury within the past six months; if they had a concussion in the past six months; if they currently have any health issues related to vestibulocochlear or balance functioning; or if they were taking any medications that can impair ability to balance properly.

Subject candidates that met the inclusion criteria, were oriented to the study and provided informed consent prior to further participation in the study (appendix C). The Humboldt State University Institutional Review Board approved this study prior to data collection. Following the orientation/consent, we then assessed each subject's climbing ability using a questionnaire adapted from Wall et al. (2004) (Appendix D), only asking specifically about indoor climbing ability. The questionnaire gathered information such as years of climbing experience, how many days per week do they climb, and what is their best current indoor redpoint ability (what is the most difficult route they can climb indoors in 2 or more attempts).

Subjects were divided into three groups decided by indoor redpoint ability: control subjects with no previous climbing experience, novice climbers (climb 2 x week, able to climb up to V3 indoors based on Hueco Scale rating), and experienced climbers (climb 3 x week, able to redpoint up to V6 indoors). The redpoint ability of indoor climbing was chosen because it is a more consistent measure for the selected climbers. Controls were chosen from a beginners weightlifting class that occurs twice a week. The class was only 50 minutes and for beginners who have never done organized weightlifting before. An additional requirement of the class was that the students do one more exercise session per week, which could be weightlifting, running, or any other type of extracurricular physical activity. The students worked out a total of 3 times per week. Since they were beginners, the potential subjects did not have any advantages in the Star Excursion Balance Test (SEBT) stemming from strength in their legs due to experience in lifting weights. For the novice climbers, being able to climb a V3 was chosen as it is a reasonable grade for someone who is still progressing in indoor climbing. The Hueco Scale ranges from V0-V16 and becomes more difficult as the numbers go higher. A V0 route is the easiest with holds that one can wrap the whole hand around or place plenty of surface area of the foot for support and involves simple movements analogous to climbing a ladder. A route with a V3 has smaller holds and movements that involve placing the body and feet in more unconventional positions. However, the amount of time it takes a beginner climber to achieve finishing a V3 route is not that long, which is why it will be termed the 'novice' group. The subjects were only allowed to report their ability as a V3 or V6 if they have been consistently climbing at that difficulty for a month.

Experimental Design

Prior to data collection, all subjects filled out a questionnaire (Appendix A) based on Wall et al. (2004) with adjustments to ask questions about bouldering performance. Questionnaires have demonstrated good reliability for accuracy of climbing ability (Wall et al., 2004; Draper et al., 2011). Although males seem to overestimate their climbing ability, T-tests show that reported versus tested climbing ability were not significantly different (Draper et al., 2011). The questionnaire covered information such as years climbing, number of days a week climbing, their current indoor flash (completing a problem on the first ascent but with previous knowledge of how to climb the route), their current indoor onsight ability, and what is their best redpoint.

Initially, active range of motion (AROM) of the ankles and hips (degrees) was determined using the method described by Overmoyer & Reiser (2015). The score of the SEBT was determined by how far the subjects reached with their big toe in each direction of the asterisk, measured in centimeters. A composite score of the cumulative total distances reached in eight directions was calculated as well.

Prior to performing range of motion and SEBT tasks, the subjects warmed up for five minutes on a stationary bike at an easy intensity and cadence. A metronome set to 144 beats/min will ensure that all subject performed the warm up at the same cadence. After warm-up, the subjects were measured for their anatomical leg length and range of motion. Following leg length and range of motion measures, dynamic balance was then measured using the SEBT. All SEBT measurements were performed for both the left and right side of the body and distances of the SEBT were normalized to leg-length [$SEBT_{norm}$ (%) = SEBT/Leg length], where leg length was measured as the distance from the anterior superior iliac spine (ASIS) to the medial malleolus.

Active Range of Motion. Active range of motion (AROM) for the hip and ankle of each leg was measured using a standard goniometer as described by Overmoyer & Reiser (2015). Hip flexion, external rotation, internal rotation and ankle dorsiflexion were measured. Previous research has shown the ranges of motion at the hip and ankle are the most influential to SEBT performances (Endo & Sakamoto, 2014; Overmeyer & Reiser, 2015; Hoch et al., 2016).

1. Hip flexion measurements had the subject supine with the fulcrum of the goniometer set on the greater trochanter of the femur, with the stationary arm along the midline of the upper body and the measurement arm pointing towards the fibular head.
2. Hip external/internal rotation were measured with subjects in a seated position with knees bent to 90 degrees. The fulcrum is aligned to the inferior aspect of the patella, the stationary arm perpendicular to the floor, and the movement arm pointed midway between the malleoli.
3. Dorsiflexon of the ankle was determined using the fulcrum on the lateral malleolus, stationary arm pointed to the fibular head, and the movement arm towards the lateral aspect of the 5^{th} metatarsal.

Star Excursion Balance Test (SEBT). Dynamic balance was assessed using the Star Excursion Balance Test. An asterisk was created on the ground using tape to form eight total excursions; each excursion being 45º from the adjacent excursion. Subjects were barefoot, with the planted foot aligned such that the first metatarsophalangeal joint was in the middle of the star. The reaching foot was extended as far as possible along each excursion line while maintaining proper posture throughout the reach. Trials were discarded and repeated if the subject removed their hands from the hips, too much weight was transferred to the reaching foot for support, the heel of the planted leg rose off the ground, the subject could not return to the starting position for a full second, or the overall quality of posture during the reach was compromised (Olmsted et al., 2002). As proposed by Robinson & Gribble (2008), four practice reaches per each excursion were allowed with a 15-second break between excursions, for a total of 32 practice reaches. After a 5-minute break, the average of three measured reaches in each direction were collected. Subjects dipped their big toes in finger paint to mark the measuring tape. Reach distances were measured to the center of each mark made by the big toe. Reach distances (cm) were then normalized by dividing scores by the subjects' leg lengths (cm). A composite score of the total distance sum of all eight normalized reaches was analyzed as well. Scores of the right and left legs in the SEBT were designated as dominant and non-dominant. This procedure was repeated bilaterally and the average of the two legs was used to calculate bilateral averages for each excursion and the SEBT composite score. The differences between reach distances of the dominant vs. non-dominant leg were calculated to explore whether climbers had similar reaches for both limbs.

Statistical Analysis

Descriptive statistics were used to describe the flexibility and leg-length characteristics of the climbers. Homogeneity of variance was assessed with Levene's Test. If homogeneity of variance was violated then the F-ratio was calculated using the Browne-Forsythe F. One-way Analysis of Variances (ANOVAs) were used to determine differences in AROM and SEBT scores between groups (SPSS version 25, Armonk, NY). I also used ANOVAs to determine any difference in SEBT symmetry (difference between dominant and non-dominant leg) between groups. Planned contrasts were used to determine specific differences between controls v climbers, novice v experienced climbers, and controls vs experienced climbers. AROM was controlled for as a covariate if there was significance for an individual range of motion. An alpha level of .05 was chosen for this study.

Assumptions and Limitations

This study had the following assumptions:

1. All subjects honestly reported 1) their climbing ability and 2) their injury history and how it may affect the results of the study. It was also assumed that the self-reported climbing ability (redpoint) is the true ability of the climber.
2. The Star excursion balance test will be an accurate and reliable measure of dynamic lower limb balance and that each subject would perform the SEBT to the best of their ability.

3. Measurements of AROM would be performed accurately and reliably on every measured joint of every subject. As well that directions for performing the SEBT would be the same for every subject.

Delimitations

1. The study only included boulderers from Humboldt County who primarily participate in bouldering. The sample population may not be representative of all climbers.
2. The study only quantified dynamic balance using the SEBT and did not evaluate any other aspects of the climbing profile besides the climbers' active range of motion.

Chapter 3: Results

Descriptive Statistics

Eighteen subjects completed the study. All subjects began and finished the study with no drop outs. There were a total of six Controls (non-climbers), five Novice climbers, and seven Experienced climbers. All subjects shared right foot dominance except for one control and one novice. Other demographic information per each group is shown below.

Table 1: Descriptive Statistics

Subject (n=18)	**Age (yrs)**	**Weight (kg)**	**Height (cm)**	**Leg Length (cm)**	**Dominant Foot**	**Climbing Ability**
Controls (n=6)	25.5±4.3	71.8±11.8	168.1±8.6	87.3±4.4	83.33% Right	NA
Novices(n=5)	20.8±4.1	64.7±9.3	173.7±7.3	90.7±4.0	80% Right	V1-V3
Experienced(n=7)	22.71±2.7	66.9±8.5	167.6±8.7	88.6±5.2	100% Right	V4-V6

Star Excursion Balance Test

Results showed main effects in the SEBT COMP scores, as well as in the POST, POSTM, and MED directions (p=.021, .013, .016, P<.0001, respectively; Table 2). Experienced climbers reached an average of 11.6% and 19.6% further than Novices in the POSTM and MED directions (p=.045, .002, respectively). Experienced climbers reached 13.7%, 13.8%, 26.5%, and 9.7% farther than Controls for COMP, POST, POSTM, and MED excursions (p=.022, .014, .018, P<.000, respectively). Overall, Climbers' combined scores were 7.8%-27.7% farther in the posterior and medial directions of the SEBT compared to Controls.

Table 2: Means and SEM of the eight directional and composite scores of the SEBT. Scores normalized to leg length

	Control	**Novice**	**Expert**	**Group Effect**
Anterior	.71±.05	.73±.00	.74±.07	P=.317
Anterolateral	.77±.05	.83±.01	.80±.06	P=.309
Lateral	.84±.07	.88±.04	.89±.07	P=.162
Posterolateral	.92±.08	.99±.01	.99±.02	P=.126
Posterior	.95±.11	.99±.08	1.08±.06†	P=.013
Posteromedial	.87±.08	.89±.08**	.99±.08†	P=.016
Medial	.68±.04*	.72±.08**	.86±.07†	P=<.001
Anteromedial	.65±.02	.66±.00	.67±.07	P=.710
Composite	6.38±.43	6.66±.31	7.00±.51†	P=.021

(*) Indicates significant difference of controls v. novices+experienced climbers (P<.05).
(**) Indicates significant difference of novices v. experienced climbers (P<.05).
(†) Indicates significant difference of controls v. experienced climbers (P<.05).

Differences in in SEBT symmetry (the difference between dominant and non-dominant legs) in the ANTL, POSTM, ANTM directions and the COMP scores were documented (p=.032, .026, .012, .016, respectively; Table 3). Experienced climbers had better symmetry compared to Novices for the POSTM direction (p=.023), but Novices had better symmetry compared to experienced climbers for COMP and ANTL scores (p=.044, .021). Experienced climbers had better symmetry compared to Controls in the POSTL and ANTM excursions (p=.027, .011). Experienced climbers only displayed the lowest difference between reaches in the POST, POSTM, and MED directions.

Table 3: Means and SEM of the Symmetry Score for the eight directional and composite scores of the SEBT

Symmetry Difference	Control	Novice	Expert	Group Effect
Anterior	.05±.04	.03±.01	.05±.01	P=.680
Anterolateral	.04±.03	.01±.01**	.05±.02	P=.032
Lateral	.04±.03	.02±.03	.05±.02	P=.493
Posterolateral	.04±.03	.04±.03	.05±.02	P=.634
Posterior	.04±.02	.04±.03	.02±.01†	P=.195
Posteromedial	.04±.03	.07±.03**	.03±.02	P=.026
Medial	.04±.04	.04±.04	.02±.01	P=.384
Anteromedial	.06±.03*	.02±.02	.02±.02†	P=.012
Composite	.23±.09	.07±.06**	.20±.11	P=.016

(*) Indicates significant difference of controls v. novices+experienced climbers (P<.05).
(**) Indicates significant difference of novices v. experienced climbers (P<.05).
(†) Indicates significant difference of controls v. experienced climbers (P<.05).

Active Range of Motion (AROM)

In contrast to the hypothesis, no differences in AROM were found related to climbing experience. Experienced climbers had 37% more hip flexion flexibility than Novices (p=.032 Table 4), but Control subjects had 30.1% greater hip flexion flexibility than Novices.

Table 4: Means and SEM of AROM (degrees)

	Control	Novice	Expert	Main Effect
Hip Flexion	75.67±4.60	58.17±2.47	80.00±20.78*	P=.073
Dorsiflexion	4.08±2.67	5.33±.29	5.43±5.18	P=.726
Hip External Rotation	29.25±9.77	29.60±3.42	27.10±1.48	P=.771
Hip Internal Rotation	32.60±3.53	37.00±6.42	34.29±9.45	P=.760

*Indicates significant difference of novices vs. experienced climbers (P<.05)

AROM symmetry was determined as the absolute value of the difference between dominant and non-dominant AROM (difference between dominant and non-dominant AROM, measured in degrees). In this study I found that Novices had 67.7-70% better symmetry in dorsiflexion than Experienced climbers and Controls as a main effect (*p*=.036, Table 5), although contrasts did not reveal any significance. No other group differences in AROM symmetry were observed. Although insignificant, Controls displayed better symmetry between limbs in both hip external and internal rotation, having 30.1% and 36.7% better symmetry compared to Experienced climbers.

Table 5: Means and SEM of Symmetry of AROM (degrees)

	Control	Novice	Expert	Main Effect
Hip Flexion	5.67±3.39	3.40±2.30	3.17±2.56	P=.147
Dorsiflexion	2.00±1.41	.60±.55	1.86±1.07	P=.036
Hip External Rotation	2.00±1.00	3.60±2.30	2.86±2.41	P=.550
Hip Internal Rotation	2.17±2.14	5.60±5.27	3.43±3.31	P=.582

Chapter 4: Discussion

The purpose of this study was to quantify lower body dynamic balance of indoor rock climbers using a scored dynamic balance test and determine if dynamic balance differed between climbers with different ability levels and to non-climbers. This study partially supports the alternate hypothesis in that more experienced climbers had greater reach distances of the SEBT compared to Novices, but only in the POSTM and MED directions.

Main effects were only found for the POST, POSTM, MED, and COMP scores where the Experienced climbers had longer reaches than Controls and Novices. Experienced climbers reached 11.6% and 19.6% further than Novices in the POSTM and MED directions. Moreover, Experienced climbers reached an average 14% farther than Controls for COMP, POST, POSTM, and MED excursions. The motion of reaching the foot out laterally to a foot-hold during climbing mimics the LAT excursion in the SEBT, but no differences were found for that measure. Twisting the torso and turning one hip towards the wall could make the reaching leg utilize more hip extension to reach a foot-hold, which might explain why experienced climbers had better scores in the POST and POSTM directions. Turning the hips obliquely towards the wall is also a movement pattern used to climb more efficiently and decrease time remaining immobile (Herault et al., 2017). Reaching in the MED direction involves kicking the reach-foot behind the stance leg. This is an uncommon position in climbing, but more difficult routes could have settings with a similar limb arrangement and thus may explain why Experienced climbers' scores were greater for the MED excursion.

It was thought that the SEBT could be applicable to bouldering since during climbing there is more time spent moving dynamically rather than statically holding a position (White & Olsen, 2009). However, for the indoor climbers used in this study, only two out of the nine measures were different between Experienced climbers and Novices, which did not agree with my hypothesis. The Experienced climbers were expected to have greater reaches in more directions compared to Novices and Controls, so there is a possibility that the SEBT is not an accurate measure of dynamic balance for climbers. Alternatively, prior research has found that upper body variables contribute the most to performance (Mermier et al., 2000; España-Romero et al., 2009), which, according to the results of this study, could still be the main contributor to the somatic profile of climbers. Overall, dynamic balance scores indicated a trend based on experience. In seven out of nine measures, there were trends of SEBT reaches improving as climbing ability increased.

Experienced Climbers displayed less symmetry between reaches, which did contrast the secondary hypothesis. The Novices had greater symmetry for the COMP and ANTL reaches, while Experienced climbers had more symmetry than Novice climbers or controls only in the POSTM excursion. Results of this study indicate that having symmetry between limbs for dynamic balance may not contribute to climbing ability. Despite our observation that experience climber have less symmetry in dynamic balance, their COMP averages were greater than Novices or Controls.

Climbers displayed poor AROM, despite having greater hip flexion than Novices (80° vs 58.17°). The Controls' average range of motion was only about five degrees less than Experienced climbers (75.67°). For the symmetry-differences in AROM, Novices had better dorsiflexion symmetry compared to Experienced climbers (0.6 vs 1.86). This would indicate that dorsiflexion is not an essential component for climbing, but these findings could be due to the sampling of climbers who participated. Although not significant, the Controls technically had less differences between limbs for both hip internal and external rotation. Data was collected towards the latter half of the semester, so the Controls from the beginners weightlifting class could have been already experienced with warm-up and stretching techniques. This could have influenced the Controls to have greater AROM than Novice climbers.

These inconsistent findings on AROM in climbers are similar to previous studies. Prior studies have found AROM to have low correlation to tested climbing performance (Mermier et al., 2000; España-Romero et al., 2009) and no differences between climbers and control subjects (Grant et al., 2001; Wall et al., 2004). Only two studies found that better climbers had significantly wider leg-span than novices and controls (Grant el al.,1996; Draper et al., 2009).

No other study has attempted to quantify dynamic balance in rock climbers and compare scores between ability levels and non-climbers. However, Draper et al. (2009) did examine the dynamic AROM of climbers of varying ability levels using four novel AROM tests. Two of the tests involved a variant of raising a foot up a flat wall and measuring the distance. The results showed significant differences in two of the foot raise tests and revealed better reaches as climbers' ability levels got better. The AROM tests Draper used did not involve balance but they were dynamic and utilized positions similar to those in the SEBT.

This study involved a novel application for examining a population of indoor climbers and it is not without limitations. The climbers were divided into groups based on a climbing questionnaire and were not tested to discern skill level, so ability was dependent on climbers honestly reporting their best redpoint ability. An injury history questionnaire was used to screen subjects involving questions if they were injured in the last six months. Any subjects with injuries older than that time frame could have affected SEBT reaches. The subjects were also not screened for previous athletic history, so certain sport backgrounds could have influenced the excursion scores. Also, when subjects were tested was not at a set time of the day; data was collected whenever it was convenient for their schedule. With this in mind, the subjects may or may not have done the SEBT or AROM to the best of their abilities due to different levels fatigue or motivation during the testing.

The subjects of this study may not represent the diverse population of climbers. Subjects were chosen from the HSU climbing club and from the local indoor gym, so they specialized mostly in indoor bouldering. Some individuals from the climbing club had only just begun climbing and had only a few months experience, so their reported ability may have been less than what they self-reported. The results of this study may not representative of the whole population of indoor boulder climbers. Outliers (< 3SD) were trimmed from the original data, which resulted in unequal numbers between groups for statistical analysis and could have affected P-values in the results.

Within the confines of the SEBT, the chosen positioning of the stance leg could have altered the reaches. The starting position required that the 1^{st} metatarsophalangeal joint be placed in the center of the SEBT; in the likelihood of a subject losing their balance and removing their stance leg it would be easier to reposition their foot to restart the test. Since this placed the feet in a more posterior position relative to the center of the star, it did appear to favor greater values in posterior excursions (Table 2).

In conclusion, the results of this study indicate that lower body dynamic balance may not contribute as much to climbing performance as hypothesized. There were differences between groups for four of the measures, with Experienced climbers producing better scores for two of those excursions. Due to the population sample of this study and small numbers of subjects, more research investigating dynamic balance in climbers is warranted. Future research could examine lower body parameters with the inclusion of strength, flexibility, and dynamic balance to discern which contributes most to a measured climbing performance. At the very least, scores of the SEBT do indicate which limb has worse dynamic balance for a climber. Maybe if a climber had a deficit in one excursion compared to the other side, they could improve their AROM and strength for that excursion and possibly improve their climbing performance.

Operational Definitions

1. **Active Range of Motion (AROM)-** the full movement of a joint actively done by an individual without any assistance
2. **Bouldering-** a subdiscipline of rock climbing. A form of solo climbing on routes that doesn't involve the use of equipment like ropes and harnesses. Problems are typically 4m high and involve overhanging surfaces more often than typical outdoor, top-rope climbing (White & Olsen, 2010)
3. **Dynamic Balance-** postural control and awareness while maintaining one's base of support through a functional task (Gribble & Hertel, 2003).
4. **Flash-** completing a problem on the first ascent but with previous knowledge of how to climb the route (rei.com)
5. **Hueco Scale (the "V" Scale)-** the most commonly used grading system for bouldering problems. A problem rated as V0 is the easiest possible problem, with holds that are big and deep enough to fit a whole hand around, and involves very basic movements of the arms and legs. Holds become smaller and moves become more technical as the grades go higher (Climbingtechniques.org)
6. **Onsight -** when you complete a problem with no practice and no previous knowledge of how the moves should be done (rei.com)
7. **Problem-** a bouldering climbing route (Macdonald & Callendar, 2011)
8. **Redpoint-** the grade of a completed problem that is done after 2 or more attempts (Wall et al., 2004)

9. **Sport Climbing-** rock climbing using pre-placed protection such as bolts or a top rope

10. **Star Excursion Balance Test (SEBT)-** a test to measure dynamic balance. Using tape, the shape of an asterisk is formed on the ground. Standing in the middle of the star, subjects will balance on one leg and reach as far as they can along the tape with the opposite leg, touching the tape with their toe. The test is scored by measuring the farthest distance

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Appendix A

Indoor Climbing Performance
Questionnaire

1. Number of years rock climbing _____________

2. Number of years indoor bouldering ___________

3. Number of days per week you climb ____________

4. Best indoor onsight (hardest problem completed on first try with no prior knowledge or advice) _____________

5. Best indoor flash (hardest problem completed on first try with knowledge of beta) _____________

6. Best indoor redpoint (hardest problem completed after 2 or more attempts) _____________

7. Current indoor flash/onsight ___________

8. Current indoor redpoint ability (2-5 attempts) _____________

Appendix B

Dynamic Balance and Flexibility of Experienced and Novice Rock Climbers

Principal Investigator: Brian Shea, BS, ATC
PARTICIPANT INFORMED CONSENT FORM

Please read the following material that explains this research study. Signing this form will indicate that you have been informed about the study and that you want to participate. We want you to understand what are you are being asked to do and what risks and benefits are associated with the study. This should help you decide whether or not you want to participate in this study.

You are being asked to participate in a research project conducted by Brian Shea under the supervision of Justus Ortega, Ph.D., Department of Kinesiology and Recreation Administration, 1 Harpst St., Arcata, CA, 95521. **Dr. Justus Ortega may be reached at (707) 826-4274 or Justus.ortega@humboldt.edu to answer any questions or concerns.**

Project Description:
When ascending a wall, a climber's feet are typically never level and are resting on holds that protrude enough for only the toes to be touching. This requires overall strength of the feet and leg musculature and also good balance to move efficiently. Previous research has shown that professional climbers have more dynamic balance than those with no climbing experience. The primary purpose of this study is to investigate the differences in dynamic balance in climbers of different ability levels. You are being asked to be in this study because you are 18-30 years of age and in good health. Participation in this study is entirely your choice.

Procedure:
If you agree to take part in this study, you will be asked to come to the laboratory for one experimental session. There is no monetary compensation for participation in this study. All experimental sessions will take place in the HSU Biomechanics Lab.
Orientation (30 minutes)

- We will explain the study and what we will ask you to do.
- You will read the informed consent.
- We will answers any questions you may have.
- You will sign the informed consent form, if you agree to participate in the study.

- You will complete a medical history questionnaire.

Warming Up (5 minutes)

- We will have you warm up on a stationary bike at an easy pace.

Leg-length and Flexibility Measurements

- After warming up we will take measurements of your anatomical leg-length while you are standing with a tape measure.
- We will then take measurements of the active range of motion of your hip (Hip flexion, extension, abduction, adduction, internal/exertnal rotation and ankle flexion/extension). We will demonstrate which movements to take your leg through and then have you do it on your own effort. We will measure range of motion with a standard goniometer.

Balance Testing

- The Star Excursion Balance Test will be done on pieces of tape on the ground that form the shape of an asterisk. It will be measured on both legs. The goal of the test is to maintain a stable base of support while attempting to reach as far out as possible with the other foot along each line of the asterisk.
    - 4 practice trials in each of the eight directions will be allowed with a short break in between (15 seconds). This will be repeated for both legs.
    - After the practice trials there will be a 5 minute rest period.
    - You will do 3 collection trials in each direction, with both legs, which will then be averaged and also added up to get a total balance score.

Participation in this study should take a total of 3 hours. In the session, the total time commitment is broken up as follows; orientation (30 minutes), and experimental trials (2.5 hours).

A maximum of 45 participants will be invited to participate in this research study.

Risks and Discomforts:

There are small potential risks if you take part in this study. During the experimental sessions there is a small risk that you might experience discomfort in your knees or ankles when doing the Star Excursion Balance Test. If any pain or discomfort is felt during any of the trials then notify the personnel and we will stop to allow a break. Although minimal, there is also some risk of falling during the dynamic balance trials. However, we have trained personnel to help prevent you from falling and safety mats will be placed around the data collection area. To further reduce the risks associated with participation in this study, all members of our research team that will be conducting this experiment are CPR, AED, and first aid certified and will provide constant supervision. Aside from these risks, none of the other procedures should cause you discomfort or injury.

Benefits:
The benefits of being in this study are: a) medical information gained through your medical history, b) gaining knowledge of your abilities of dynamic balance and flexibility and knowing which areas to improve upon, and c) helping to add to the growing field of research in rock climbing.

Subject Payment:
You will not be paid for participation in this research study.

Injury and Compensation:
If you feel that you have been harmed while participating in this study, you should inform the faculty supervisor, Dr. Justus Ortega, (707) 826-4274 immediately. If you are injured, Humboldt State University will not be able to pay for your medical care. State law may limit Humboldt State University's legal responsibility if an injury happens because of this study.

Study Withdrawal:
You have the right to withdraw your consent or stop participating at any time. You have the right to refuse to answer any question(s) or participate in any procedure for any reason.

Confidentiality:
We will make every effort to maintain the privacy of your data. From the beginning of your participation, you will be given a unique identity code. This code will be used instead of your name for all documentation of your participation. We will keep your individual data and results confidential including computer files, paper files, and any personal information. In written or oral presentations of the results of this research, your identity and individual information will be kept confidential. After the project is complete, the materials associated with the project, including computer files, paper files, digital video files, and personal information will be secured in a locked cabinet in a locked office under the supervision of Dr. Justus Ortega for five years in case there is a need for future verification or reanalysis of the data. Upon completion of this informed consent form, you will receive a signed copy of the consent form.

Other than the research team, only regulatory agencies, such as the Humboldt State University Committee for the Protection of Human Subjects in Research may see your individual data as a part of routine audits.

Invitation for Questions:

If you have questions about this study, you should ask the researcher before you sign this consent form. **You may also contact Brian Shea, the primary investigator, to answer any questions or concerns regarding the study at** bgs11@humboldt.edu **or (510) 904-7153. If you have additional questions or concerns you may also contact Dr. Justus Ortega, the faculty supervisor at** justus.ortega@humboldt.edu **or (707) 826-4274.**

If you have any concerns with this study, contact the Interim Dean for Research & Sponsored Programs, Steve Karp, at karp@humboldt.edu or 707-826-4190

Authorization:

I have read this consent form. I understand the possible risks and benefits. I have received, on the date signed, a copy of this document containing 4 pages. I understand that the researcher will answer any questions that I may have concerning the investigation or procedures at any time. I also understand that my participation in this study is entirely voluntary and that I may decline to enter this study or may withdraw from it at any time without any penalty. I understand that the investigator may terminate my participation in the study at any time.

Name of Participant (printed) ____

Signature of Participant ___________________________ Date ______________.
(Also initial all previous pages of the consent form.)

For IRB Use Only

Appendix C

Demographic & Injury Questionnaire

Name____________________________ Gender_______ Age_________

Email_____________________________ Cell #_________________________

Height__________ Weight__________ *Dominant Leg: Left______ Right______

*Which leg would you use to kick a soccer ball

Please answer the following questions honestly. This will allow me to see if you qualify for the study. If you have any questions please email me at bgs11@humboldt.edu, or call/text me at 510-904-7153.

Thank you,

Brian Shea, ATC

Please check Yes/No for the following questions:

1. Have you ever been diagnosed with a balance disorder? Yes____ No____
2. Have you had an ankle sprain in the last 6 months? Yes____ No____
3. Have you had a concussion in the last 6 months? Yes____ No____
4. Have you had 4 or more ankle sprains in the past year? Yes____ No____
5. Do you feel like your ankle "gives away"? Yes____ No____
6. Have you ever had any surgeries in the lower extremity or brain

   that could affect your balance? Yes____ No____
7. Are you taking any medication that could impair your balance? Yes____ No____

If answered yes to any previous questions, please explain

____

____