COORDINATION OF HANDWALKING IN GYMNASTS: A COMPARISON TO BIPEDAL WALKING

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Abstract

Handwalking is a skilled movement that many, if not most, individuals never master. However, mastery of handwalking is critical to successfully compete in gymnastics. Understanding the patterns of movement employed to achieve handwalking may provide insights into the coordination of handwalking and strategies that may be effective for improving handwalking performance. The aim of this study was to characterize the spatiotemporal features of handwalking in gymnasts, compare these features to those of typical walking, and determine how these features vary as a function of skill level. Nineteen gymnasts performed handwalking and bipedal walking trials on a computerized walkway. Participants used nearly identical cadences for handwalking and bipedal walking. Differences between handwalking and bipedal walking included shorter strides, a wider base of support, and more time spent in double support during handwalking. The increase in double support time may be a strategy adopted to enhance stability, as level of gymnastics skill was positively correlated with the amount of time spent in double support, i.e. with both hands in contact with the ground, during handwalking. Coaching strategies that encourage increasing the amount of time spent with both hands in contact with the floor may be advisable to improve handwalking performance.

Keywords: *coordination, gymnastics, handwalking, locomotion.*

INTRODUCTION

Handwalking is a form of skilled movement that many, if not most, individuals never master. However, many gymnasts do master this skill and perform it successfully on a regular basis. Understanding the patterns of movement employed to achieve handwalking may provide insights into the coordination of handwalking and strategies that may be effective for improving handwalking performance. No studies to date have examined handwalking performance, but a few studies have examined postural control during maintenance of a handstand (Kerwin and Trewartha, 2001, Gautier, Thouvarecq, and Chollet, 2007). The handstand has been characterized as an upright stance requiring precise coordination of multiple joint segments and utilizing vestibular, proprioceptive and visual feedback, similar to bipedal standing posture (Gautier, Thouvarecq, and Chollet, 2007). Furthermore, the displacements of center of pressure and body segment angles between three articular levels (shoulder, elbow, and wrist) have been found to reflect traditional erect posture (Kerwin and Trewartha, 2001). It has been suggested that similar control mechanisms may regulate maintenance of upright posture on the hands or the feet (Gautier, Thouvarecq, and Chollet, 2007). The aim of this study was to characterize handwalking patterns in gymnasts, compare these patterns to those of bipedal walking, and determine how patterns differ as a function of skill level.

METHODS

Participants

Nineteen gymnasts (18 female and 1 male, average age =16.9 +/- 5.7 years, age range = 7-25 years) participated in this study. Skill levels ranged from Junior Olympic competitive level 5 through collegiate level gymnastics. Inclusion criteria included the ability to maintain a straight body handstand with no assistance and to handwalk for at least 15 feet in that position with no assistance. Leg length was obtained by measuring the distance from the greater trochanter to the floor, and arm length was obtained by measuring the distance from the acromion to the floor (in the handwalking position). Written informed consent for minor subjects was obtained from guardians, while adult participants provided their own written informed consent. The protocol was approved by the Human Research Protection Office of the Washington University School of Medicine and was carried out according to the Declaration of Helsinki.

Procedures

Each participant completed three trials each of bipedal walking and handwalking. All walks were captured using a 4.8m GAITRite computerized walkway (CIR Systems, Inc., Havertown, PA). Order of the tasks was randomized, with the 3 trials of each task performed in a block. The primary variables of interest were velocity, stride length, cadence, width of the base of support (BOS), and percent of the gait cycle spent in stance and double support (i.e. with both hands or both feet in contact with the floor). In addition, velocity and stride length were normalized to arm and leg lengths of each participant for handwalking and bipedal walking, respectively. We also assessed variability of several of these measures. Paired t-tests were used to compare values between handwalking and bipedal walking. Wilcoxon signed rank tests were used when data were not normally distributed. Correlations between handwalking and bipedal walking variables were obtained using Pearson correlation coefficients. Finally, for the handwalking data, we determined correlations between highest competitive level in gymnastics and each of the spatiotemporal variables. For all tests, a significance level of $p \leq 0.05$ was chosen.

RESULTS

Participants walked more slowly on the hands than on the feet. The average handwalking velocity was 0.53 ± 0.13 m/s and average bipedal walking velocity was 1.17 ± 0.16 m/s. Differences in velocity between handwalking and bipedal walking were still significant when these velocities were normalized to arm or leg length (Figure 1A). Participants also took shorter strides during handwalking (0.56 ± 0.12 m) than during bipedal walking (1.21 ± 0.11 m). Differences in stride length remained significant after normalization to arm or leg length (Figure 1B). Participants used similar cadences for handwalking and bipedal walking (Figure 1C), but used a much wider base of support in handwalking as compared to bipedal walking. Participants spent a significantly larger portion of the gait cycle in stance and double support during handwalking as compared to bipedal walking (Figure 1E, F).

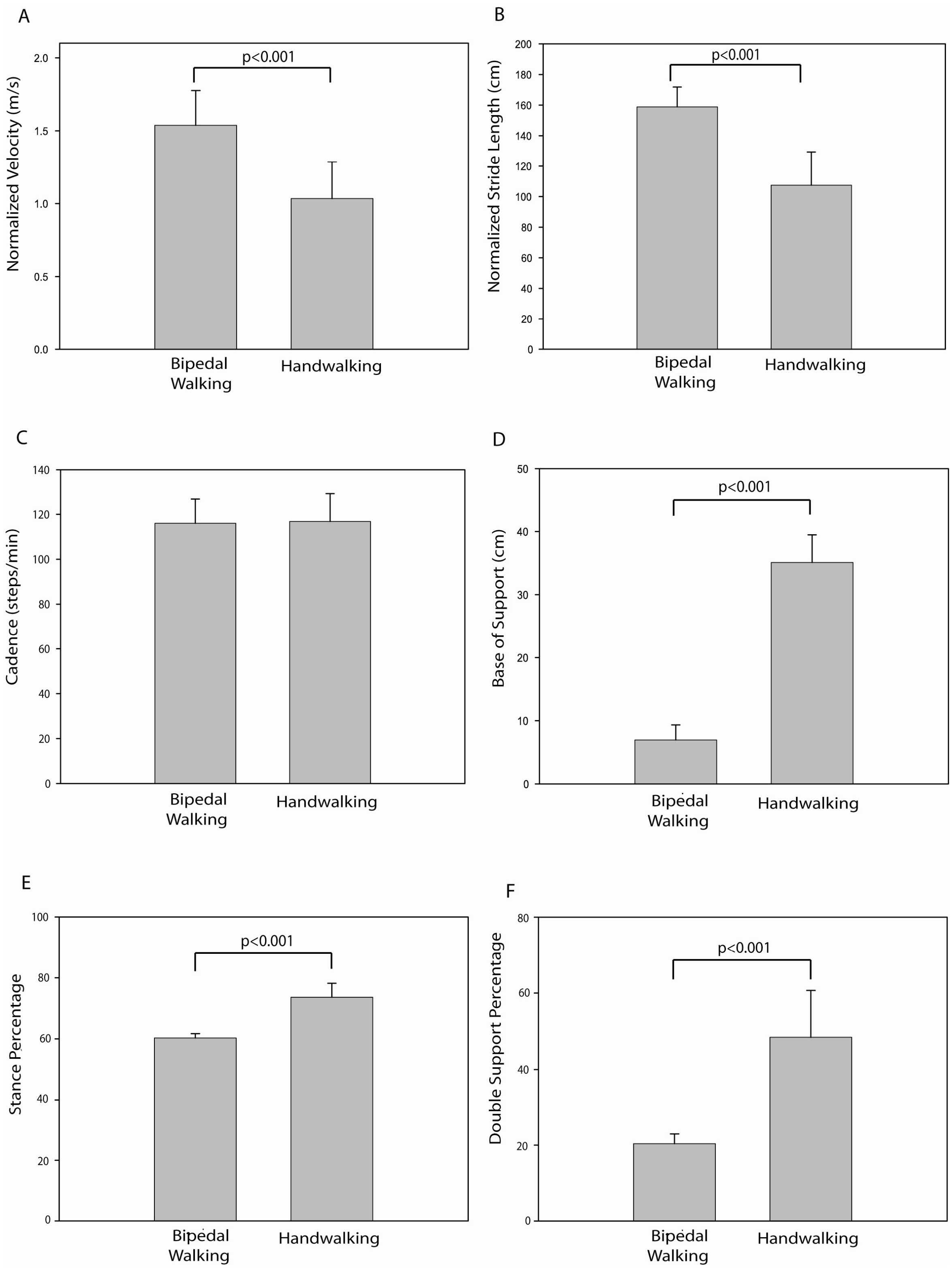

Figure 1. *Group average +/- SD values for normalized velocity (A), normalized stride length (B), cadence (C), base of support (D), stance percentage (E), and double support percentage (F) for handwalaking and bipedal walking.*

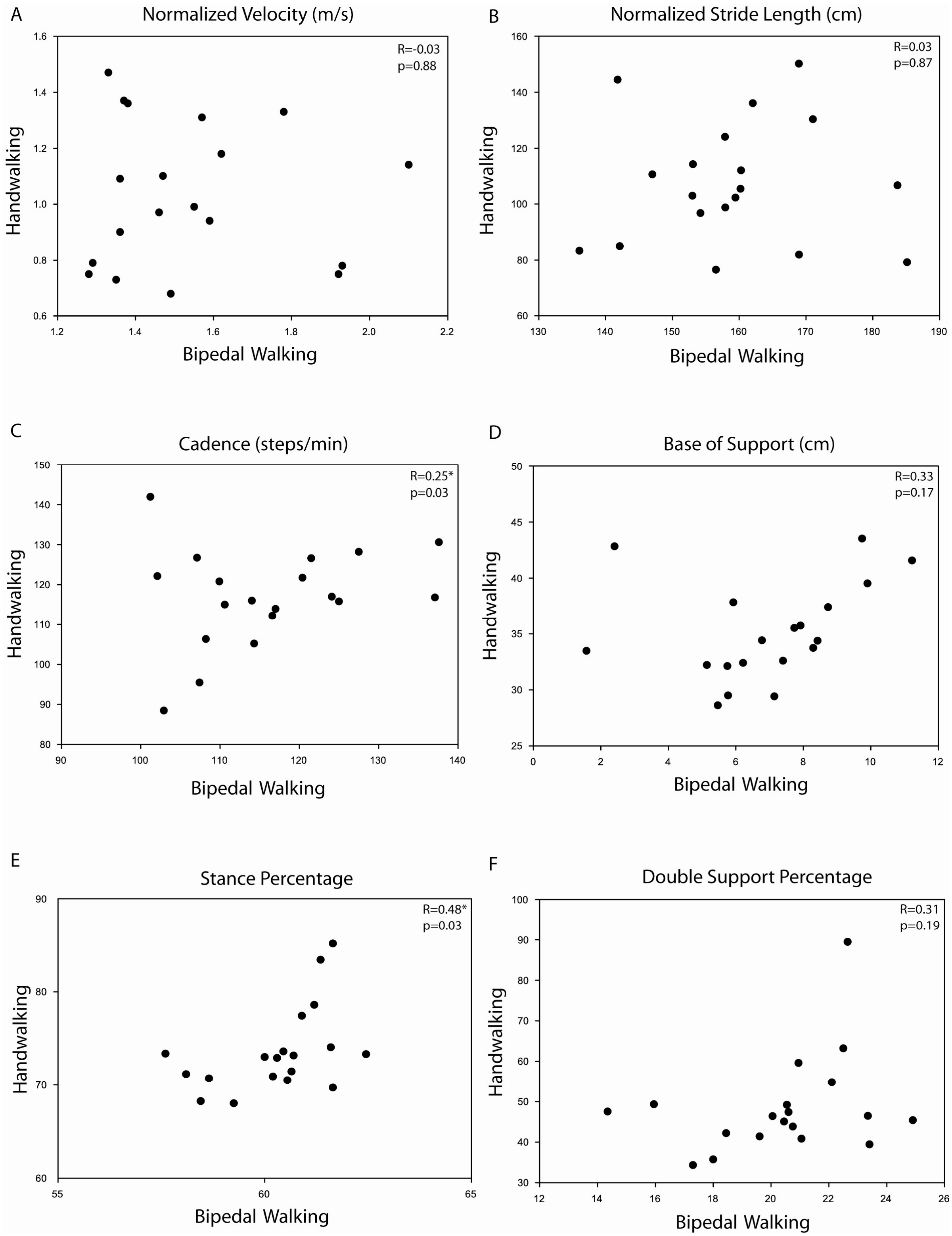

Figure 2. *Scatterplots showing the relationship between values obtained for handwalking (y-axis) and bipedal walking (x-axis) for normalized velocity (A), normalized stride length (B), cadence (C), base of support (D), stance percentage (E), and double support percentage (F).*

Participants were generally more variable in handwalking than in bipedal walking. Average stride-to-stride variability of stride length was 3.3 cm for bipedal walking and 8.1 cm for handwalking ($p < 0.001$). Average stride-to-stride variability in double support percentage was 2.1% for bipedal walking and 19.2% for handwalking ($p < 0.001$). Average stride-to-stride variability of BOS was 2.6 cm for bipedal walking and 3.8 cm for handwalking ($p = 0.01$). Correlational analyses showed only two significant correlations between handwalking and bipedal walking variables (Figure 2). These were for cadence and percentage of the gait cycle spent in stance (Figure 2E). Individuals who spent more time in stance in bipedal walking also spent more time in stance during handwalking. Highest competitive level of gymnastics experience was positively correlated with arm length and handwalking stride length and percentage of the handwalking cycle spent in stance and double support. Highest competitive level was negatively correlated with double support percentage variability (Table 1). Competitive levels were determined using the USA Gymnastics Junior Olympic system (2010).

Table 1. *Correlations of Highest Competitive Gymnastics Level with Handwalking Performance.*

Variable	Correlation Coefficient	P Value
Arm Length	0.76	< 0.001
Stride Length	0.48	0.04
Stance Percent	0.45	0.05
Double Support Percentage	0.58	0.01
Double Support Percentage Variability	-0.53	0.02

DISCUSSION

The only similarity between handwalking and bipedal walking was cadence. There were distinct differences in stride length between handwalking and bipedal walking even when limb length was taken into consideration. This likely stems at least in part from the differing biomechanical constraints at the shoulder versus the hip in the handwalking and bipedal walking positions, respectively. In the handstand position the shoulder is much closer to the maximum limit of shoulder flexion than is the hip in an upright standing posture. As such, there is less available range at the shoulder during handwalking than at the hip during bipedal walking. Given these constraints it is not surprising that stride lengths in handwalking were shorter than those in bipedal walking. The reduced stride length, despite similar cadences, contributed to the slower velocity of handwalking as compared to bipedal walking.

Biomechanical factors may also contribute to the wider BOS used in handwalking as compared to bipedal walking. The presence of the head interposed between the upper extremities during handwalking may physically limit how narrow the BOS can reasonably be in handwalking. In addition, the wider BOS in handwalking may serve to provide greater stability in the mediolateral direction during handwalking.

Handwalking not only had a wider BOS, but also higher stance and double support percentages than bipedal walking. The increase in stance and double support may be a function of the slower velocity of handwalking, as slower velocities have been associated with increased stance and double support in bipedal walking (Murray, Mollinger, Gardner, and Sepic, 1984). Alternatively, or in addition, the increase in stance and double support may be a strategy to compensate for the less stable handwalking position. Interestingly, more highly skilled gymnasts demonstrated higher stance and double support percentages along with a decrease in the variability of double support percentage as compared to less experienced gymnasts. Perhaps experienced gymnasts are better able to adopt the increased stance/double support strategy and can more tightly regulate and reproduce this strategy from stride to stride. This would suggest that the strategy of increased stance/double support is at least in part a learned approach to the task that is effectively used by higher level gymnasts. Adoption of similar strategies of increased stance and double support percentages has been noted in elderly individuals (Winter, Patla, Frank, and Walt, 1990) and in healthy young people in situations where stability is reduced, such as walking on slippery surfaces (Marigold and Patla, 2002). Another possibility is that the increase in double support is a reflection of more deliberate and controlled handwalking. Less skilled gymnasts may not be able to control vertical body position as effectively and may, therefore, sometimes resort to moving the hands to reposition the base of support in order to prevent a fall when the center of mass begins to move as a result of body sway. More experienced gymnasts who are better able to control the handstand position may as a result spend more time in double support because they are able to maintain desired body alignment and take steps when they choose to rather than when they have to do so to prevent a fall.

The positive correlation between gymnastics skill level and arm length or stride length in the present sample may be simply a reflection of the fact that the gymnasts competing at higher levels were older and thus had longer arms providing for longer strides. The general lack of correlations between handwalking and bipedal walking variables suggests that skill in one task does not transfer to the other. This is in agreement with prior work demonstrating no relationship between balance performance in a handstand position versus in an erect posture (Asseman, Caron and Cremieux, 2004).

Several study limitations should be mentioned. These include a relatively small sample size, lack of data for bipedal walking at a speed matched with that of handwalking, and lack of 3-D kinematic data regarding joint angles and movement of specific body segments. As this study is the first ever evaluation of handwalking coordination, it provides preliminary observations that support future work with larger samples, matched speeds, and more sophisticated analyses of movement.

CONCLUSION

The patterns used for handwalking and bipedal walking are quite distinct from one another in several respects, perhaps due in large part to biomechanical constraints and the inherently less stable handwalking position. More skilled gymnasts spend more, rather than less, time with both hands in contact with the ground and are less variable from stride to stride. This knowledge may be used to develop specific coaching strategies for improving handwalking performance. Encouraging longer periods of double support and more consistent stride to stride performance are specific strategies that may be coached, as these are the strategies adopted by more skilled gymnasts.

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