# EFFECT OF HEAD POSITION ON CENTRE OF MASS VARIABILITY DURING HANDSTAND: PRELIMINARY RESULTS

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The aims of this study were: a) to determine to determine the change in joint angle kinematic variability during the handstand with different head positions, and b) to determine the contributions made by wrist, shoulder, and hip joint angles variability on CoM variability in handstand. Four young active female gymnasts performed 3 trials of handstands with three head positions (normal, straight, and flexed). 3D kinematics were collected for each trial. Statistical differences were analysed using One-way ANOVA and effect sizes (ES) reported. Forward stepwise regression was carried out between CoM variability and joint angle variability. The prevalent control strategies were at the shoulder with straight and flexed head position, and hip strategy in normal head position.

**KEY WORDS:** balance, handstand, kinematics, variability.

## INTRODUCTION:

Bernstein's theory describes human movement as a coordinated and controlled process of matching, selecting, and efficiently using the various biomechanical degrees of freedom involved in solving a movement task. A fundamental question of this theory is how the control system constrains the possible solutions and how it selects an effective solution for a given movement task (Bernstein, 1966). An important processes of movement control is the maintenance of balance. Balance underlies postural actions and requires a coordinated response of the control system via information received from the proprioceptive, visual, and vestibular systems (Kerwin & Trewartha, 2001). Balance control strategies are developed during postural activities by organising muscle contractions around joints to stabilise the position of the centre of mass (CoM) (Winter, 1995). To evaluate the CoM position kinematic and kinetic analysis of the motion of all involved segments and joints is then required (Winter, 1990), and usually assessed by analysing the change in angle of each body segment as a kinematic chain or joint position (Blenkinsop et al., 2017). The handstand is a basic skill in gymnastics due to its link within more complex skills and the fact that it is performed on all apparatus in both male and female gymnastics. The handstand also represents an important postural position that can contribute to the understanding of the underlying mechanisms of balance maintenance (Asseman & Gahery, 2005). It has been found that compared to the upright stance, balance strategies during handstand are limited (Clément and Rezette, 1997; Gautier et al, 2007). Previous studies in this area have analysed strategies during different conditions such as vibration of the base support (Blenkinsop et al., 2017), changes in visual control (Gautier et al., 2007), experience of the movement task (Wyatt et al., 2021) or varying head position (Asseman & Gahery, 2005). Based on previous research, it has been proposed that the goal of postural regulation during balance movement tasks is to stabilize the head in space (Robertson, 1973). However, this may limit the influence of certain segments to maintain balance. Further, the potential influence by which the various joints involved in maintaining balance during handstands may be limited, particularly if the position of the head and the role of vision are altered. Therefore, the aims of this study were: a) in terms of Bernstein's degrees of freedom theory to determine the change in joint angle kinematic variability during the handstand with different head positions, and b) to determine the contributions made by wrist, shoulder, and hip joint angle variability on CoM variability in handstand with different head positions.

## METHODS:

**Participant:** Four female gymnasts experienced at balancing in handstand were recruited for this study (age 21.0 ± 1.9 years, height 162.0 ± 4.4 cm, and mass 55.8 ± 5.1 kg). All gymnasts had more than 10 years' experience of gymnastics training and competitive gymnastics at national level were able to maintain balance in the handstand position for at least 30 s (Blenkinsop et al., 2017). All gymnasts were injury free at the time of testing and informed consent was obtained in accordance with the guidelines of the Institute's Ethics and Research Committee.

**Protocol and Data Collection:** The gymnasts completed their self-selected warm up and completed several practice handstands trials with different head positions. After the warmup and practice, all gymnasts performed three trials of handstands with a normal, straight, and flexed head positions. All trials were performed in random order and separated by a one-minute rest period. Data were recorded for each gymnast executing a series of handstand balances of 8-10 seconds duration and used for further analysis. During all trials, gymnasts were instructed to maintain a static base of support, and attempt to remain in, or return to, the standard starting position of fully extended arms, trunk, and legs with feet together for handstand trials. This procedure was previously used in the study by Blenkinsop et al. (2017). Kinematic data were recorded using 16 Qualisys cameras (Qualisys Oqus, Sweden) sampling at 240 Hz, synchronized with ground reaction force data from a two Kistler force plates (Kistler, Switzerland) operating at 1200 Hz. In total 36 active markers and eight clusters with four markers were fitted bilaterally to each gymnast on the lower extremities, pelvis, lumbar spine, torso, upper extremities, and head. Participants wore shorts and a cropped top to allow for maximal marker placement directly onto the skin.

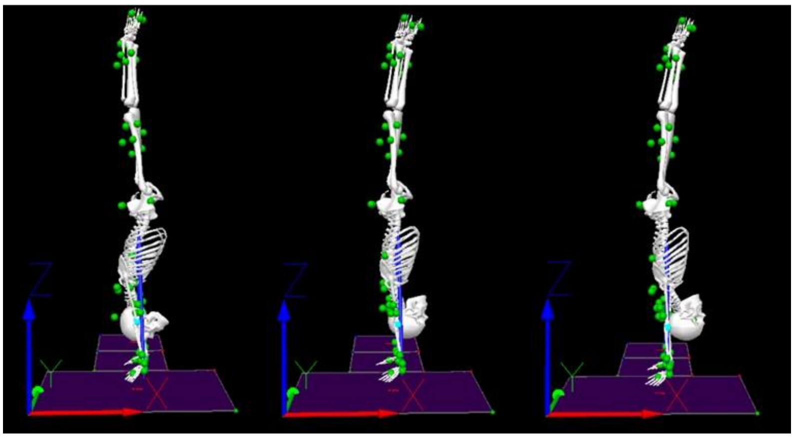

**Figure 1: Head positions (from left to right – normal, straight and flexed)**

**Data Processing and Analysis:** Kinematic data were calculated in Visual 3D software (v6, C-motion, Inc., Rockville, MD) for the inverted stance durations of three trials for each gymnast. Whole-body CoM was calculated as a weighted average of 16 segments (feet, shanks, thighs, pelvis, lumbar spine, torso, hands, forearms and upper arms, and head), using individual Visual 3D models, in accordance with previous work by Wyatt et al. (2021). Mean standard deviations for joint angle and CoM position across three trials were calculated and used for statistical analysis. Variability was calculated and expressed as standard deviation across trials. Using SPSS software (IBM SPSS Statistics 25, SPSS Inc., Chicago, IL), the statistical differences between normal, straight, and flexed head positions were analysed using One-way ANOVA, followed by Holm corrections. In addition, Cohen´s d effect sizes (ES) incorporating the pooled standard deviation were used and ES interpreted as <0.2 trivial, 0.21-0.5 small, 0.51-0.8 medium and >0.8 large (Cohen, 1992). Forward stepwise estimation regressions carried out on CoM variability as the dependent variable against joint variability as independent variables determined which joint variability were prominently related to CoM variability.

**RESULTS:** Figures 2 illustrate the dispersion variability (SD) of the joint angles (◦) during each posture.

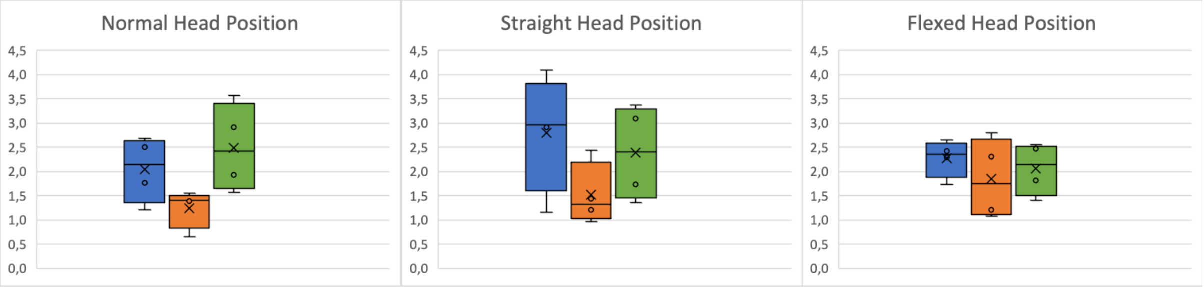

**Figure 2: Variability (SD) of the joint angles (◦) during each head posture (blue-wrist, orange-shoulder, green-hip)**

One-way ANOVA found no significant differences between normal, straight, and flexed head positions. However, large ES (ES=1.1) were found for wrist joint between normal and straight head position. For shoulder joint variability large ES (ES=1.4) were found between normal and flexed head position. As for hip joint variability large ES (ES=0.8) were found between straight and flexed head position. Large ESs were found for CoM variability between normal and straight head positions (ES=1.1) and between normal and flexed head positions (ES=1.5) (Figure 3). Table 1 shows inter and intra-individual variability (SD) across three handstand trials, suggesting that handstand with normal head position appears to be the most stable position according to CoM variability.

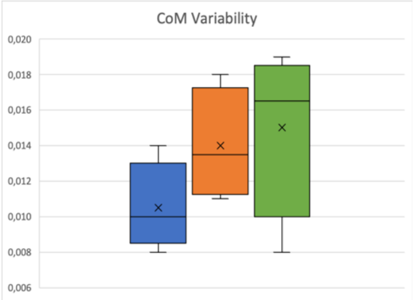

**Figure 3: Variability of CoM during each head posture (blue-normal, orange-straight, green-flexed)**

**Table 1: Inter and Intra-individual variability (SD) of the joint angles (◦) during each head position**

| | Normal | | | | Straight | | | | Flexed | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CoM** | **W** | **S** | **H** | **CoM** | **W** | **S** | **H** | **CoM** | **W** | **S** | **H** |
| **G1** | 0.014 | 2.675 | 1.394 | 3.564 | 0.018 | 4.087 | 2.444 | 3.363 | 0.016 | 1.733 | 1.068 | 1.401 |
| **G2** | 0.010 | 1.215 | 1.405 | 2.904 | 0.012 | 1.163 | 0.967 | 1.726 | 0.019 | 2.289 | 2.797 | 2.543 |
| **G3** | 0.010 | 2.503 | 1.543 | 1.562 | 0.015 | 3.002 | 1.428 | 1.355 | 0.017 | 2.648 | 2.300 | 2.474 |
| **G4** | 0.008 | 1.772 | 0.641 | 1.925 | 0.011 | 2.916 | 1.203 | 3.093 | 0.008 | 2.421 | 1.204 | 1.813 |
| **M** | 0.010 | 2.041 | 1.246 | 2.489 | 0.014 | 2.792 | 1.510 | 2.384 | 0.015 | 2.273 | 1.842 | 2.058 |
| **SD** | 0.002 | 0.535 | 0.335 | 0.718 | 0.002 | 0.939 | 0.508 | 0.779 | 0.004 | 0.462 | 0.656 | 0.559 |

Notes: M, mean; SD, standard deviation; CoM, Centre of Mass; H, hip; S, shoulder; W, wrist

Table 2 illustrates the outcome of the multiple regression, highlighting the predictor variables for CoM motion in all three head positions for joint angles variability.

**Table 2: Stepwise estimation multiple regressions for different head positions.**

| **Head Position** | **Adjusted $R^2$ in Final Model** | **Order of Inclusion** | **Joint %Predictor** |
|---|---|---|---|
| **Normal (1)** | 0.96 | H, W, S | H(39%), W(17%), S(12%) |
| **Straight (2)** | 0.99 | S, W, H | S(63%), W(33%), H(2%) |
| **Flexed (3)** | 0.99 | S, W, H | S(45%), W(37%), H(7%) |

Notes: H, hip; S, shoulder; W, wrist

**DISCUSSION:** The main goal of handstand skill is to maintain balance which may be limited, particularly if the position of the head and in turn the role of vision are altered. Therefore, the aims of this study were: a) to determine how, the variability of joint angle changed during handstands with different head position, and b) to determine the contributions made by wrist, shoulder, and hip joint angle variability on CoM variability in handstand. The results of this study suggest that handstand with normal head position appears to be the most stable position according to CoM variability (Table 1 and Figure 3). This could be explained by the fact that this head position could be most common during practice of these group of gymnasts. This is in accordance with previous research by Asseman and Gahery (2005) who highlighted that postural variability was improved in the normal (standard) and dorsiflexion positions compared with straight (aligned) and ventroflexion (flexion). This could be explained with role of vision in handstand positions where vision plays a major role to maintain balance (Gautier et al., 2007). The results of the study suggest that with a change in head position during handstand, the order of the joint contribution to maintain balance and stability of the CoM is reversed in straight and flexed positions compared with normal head position (Table 1). In a straight and flexed head position, shoulder joint angle variability had the most dominant role accounting for CoM variability, followed in order by wrist and hip joint angle variability (Table 2). In contrast during the normal head position hip joint angle variability was the highest predictor for CoM variability followed by wrist and shoulder (Table 2). Further research will focus on the inter joint coordination and coordination variability across a larger cohort of gymnasts and investigate dynamical handstand tasks on different environments.

**CONCLUSION:** During handstand tasks the prevalent control strategies was the shoulder strategy in handstand with a straight and flexed head position, and hip strategy in normal head position respectively. Our findings support the idea that the pathway of change in organization of the joint motions depends on the task dependant motions. To determine the relative variability of different strategies the CoM variability is generated by a mixture of multi-joint control that may be effective for a variety of handstand situations.

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Acknowledgements:

This research was supported by the grant “Healthy Aging in Industrial Environment” [program 4 HAIE CZ.02.1.01/0.0/0.0/16_019/0000798] and by a student’s university grant of University of Ostrava.