DO FEMALE WEIGHTLIFTERS SNATCH DIFFERENTLY? ANALYSIS OF BARBELL KINEMATICS USING STATISTICAL PARAMETRIC MAPPING

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This study aimed to analyse gender differences in barbell kinematics of the snatch in international elite weightlifters. At the 2019 Senior World Championships, horizontal and vertical barbell kinematics of the 1RM snatch lifts of the top 5 female and male weightlifters of all 10 body weight categories were assessed using two-dimensional video analysis (50 Hz). Gender differences were analysed for kinematic time series data using statistical parametric mapping. Results revealed almost similar mean snatch barbell trajectory and velocity pattern for female compared to male weightlifters. Significant differences were detected during the 1st pull with lower barbell distance and velocity. However, the few sex differences may be attributed to the high variability of barbell kinematic parameters, which are due to the dependency on body weight.

KEYWORDS: gender difference, weightlifting, trajectory, velocity.

INTRODUCTION: Weightlifting is no longer a men's sport. Over the last two decades, female weightlifters have become more professional, stronger, and more equal (e.g. the same number of body weight categories as men). However, comprehensive and actual research on women's weightlifting is still rare. Analysis of barbell kinematics (e.g., barbell trajectory) in competitions is an easy but very useful procedure to investigate sports technique and physical abilities of weightlifters (Isaka et al., 1996; Kipp & Harris, 2014). In this context, most of the research on female weightlifters has been conducted to descriptively analyse barbell kinematics or to compare female weightlifters from different performance levels (Akkuş, 2012; Okada et al., 2009). Nevertheless, relatively little evidence exists on the potential differences of female weightlifters compared to their male counterparts. Only two studies currently exist that focused on the comparison of barbell kinematics of female versus male weightlifters and highlighted differences in vertical barbell displacement and maximal vertical barbell velocity (Gourgoulis et al., 2002; Harbili, 2012). The generalizability of the aforementioned studies is limited due to the small sample size of the groups, the analysed body weight categories, or the inclusion of national weightlifters only. Furthermore, the sex comparisons were based on discrete data points (e.g., maximal vertical velocity) without considering the entire time series data of barbell kinematics. In contrast, the analysis of time series data presents more holistic insights into biomechanical differences during weightlifting exercises (Kipp et al., 2021). Therefore, the primary study aim was to compare time series barbell kinematics during the snatch of international male and female weightlifters across all body weight categories. Based on the results of prior studies, we hypothesized that female weightlifters show higher vertical barbell velocity and displacement. As body weight affects kinematic barbell parameters in female and male weightlifters (Cunanan et al., 2020), the secondary study aim was to analyse the association of kinematic parameters with body weight. We hypothesized that body weight positively correlates with kinematic barbell parameters without sex differences.

METHODS: Barbell kinematics of the snatch 1RM lifts were assessed from the top 5 female and (age: 25.3±3.3 years, body weight: 69.7±20.7 kg) male (age: 25.0±3.3 years, body weight: 88.0±26.8 kg) weightlifters of all 10 body weight categories (N = 100) at the 2019 IWF Senior World Championships (Pattaya, THA). The snatch lifts were video recorded and analysed using a custom-made real-time barbell tracking software (Realanalyzer, IAT, Leipzig, Germany) (Sandau et al., 2019). The camera (Canon, Legria HF G26, 50 Hz) was placed at a distance of 30 m and 2 m above the lifting platform almost perpendicular to the plane of lifting. From the two-dimensional video analysis, horizontal (x) and vertical (y) barbell displacement during the snatch was measured (i.e., barbell trajectory). Horizontal and vertical barbell velocity was calculated as 1st derivatives of barbell displacement. The analysed snatch movements were separated into lifting phases, based on barbell kinematics and the visually assessed body positions during the lifts: 1st pull (lift-off to the first maximum of knee extension), transition (end of first maximum knee extension to first minimum of knee flexion), 2nd pull (end of first minimum of knee flexion to maximal vertical barbell velocity [vmax]), turnover (vmax to maximal vertical barbell drop velocity [vmin]) and catch (vmin to deep squat position). These aforementioned phases were used to temporally align (0-100 %) single time series waveforms of horizontal and vertical barbell position and velocity using piecewise linear length normalization (Helwig et al., 2011). The aligned and time-normalized kinematic time series data were used for the statistical analyses. To analyse time series barbell displacement and velocity of the snatch between female and male weightlifters, statistical parametric mapping was used. First, two-sample Hotelling´s T^2 tests were used to test for multivariate (i.e., global) mean differences of barbell displacement and velocity time series data. Second, in case of significant global mean differences ($p \leq 0.05$), post-hoc two-sample t-tests were conducted for horizontal and vertical barbell position and velocity with a corrected Sidak threshold of $p \leq 0.0253$. Finally, a regression analyses was calculated to determine the effect of body weight on time series horizontal and vertical barbell kinematics. Statistical significance of associations was set at a corrected Sidak threshold of $p \leq 0.0253$. All statistical analyses were performed with the "spm1d" package in Python (Pataky, 2012).

RESULTS: For the barbell trajectory, global significant mean differences have been detected during the end of the 1st pull to the start of the transition (time range 22-40 %) (Figure 1). Post-hoc analyses revealed only for the vertical (y) direction a significantly smaller displacement in female weightlifters during the aforementioned lifting phases. However, no significant difference has been detected for the horizontal (x) displacement of the barbell. In general, female weightlifters showed a similar overall barbell trajectory pattern with the trend only for smaller vertical displacement.

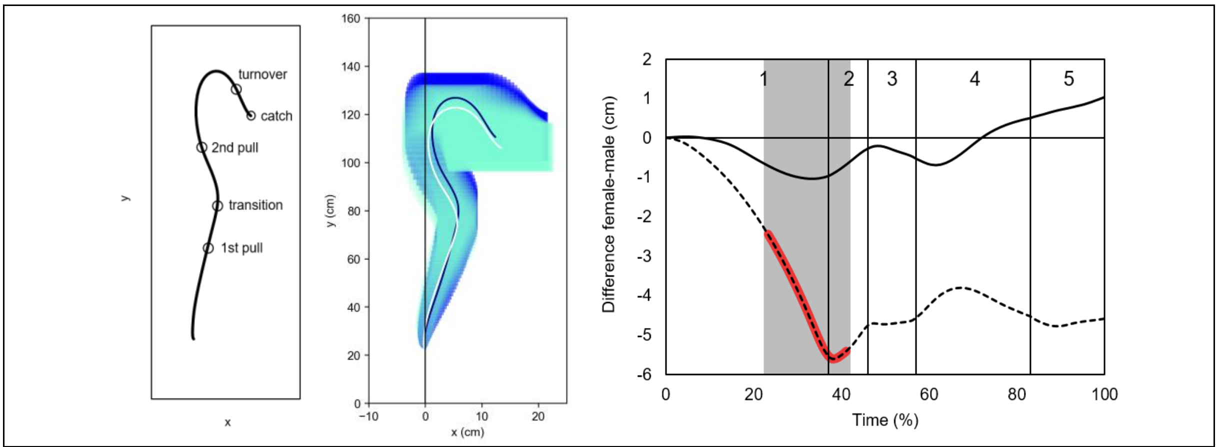

Figure 1: Left: Typical snatch barbell trajectory of the left barbell side with circles indicating the ends of the corresponding lifting phases. Center: Mean barbell trajectory for female (white) and male (blue) with standard deviations. Right: Absolute mean differences for horizontal (solid line) and vertical (dashed line) barbell displacement. Grey shaded area represents significant difference of Hotelling's test and red highlighted section represents significant difference of post-hoc t-test. Lifting phases for the snatch are coded as: 1st pull (1), transition (2), 2nd pull (3), turnover (4), catch (5).

For barbell velocity, global statistically significant differences have been detected during the 1st pull (time range 16-23 %) and at the end of the 1st pull to the start of the transition (time range 35-42 %) (Figure 2). However, post-hoc t-tests did not detect significant differences in horizontal or vertical barbell velocity. However, female weightlifters have a trend for smaller vertical barbell velocity at the end of the 1st pull and the start of the transition.

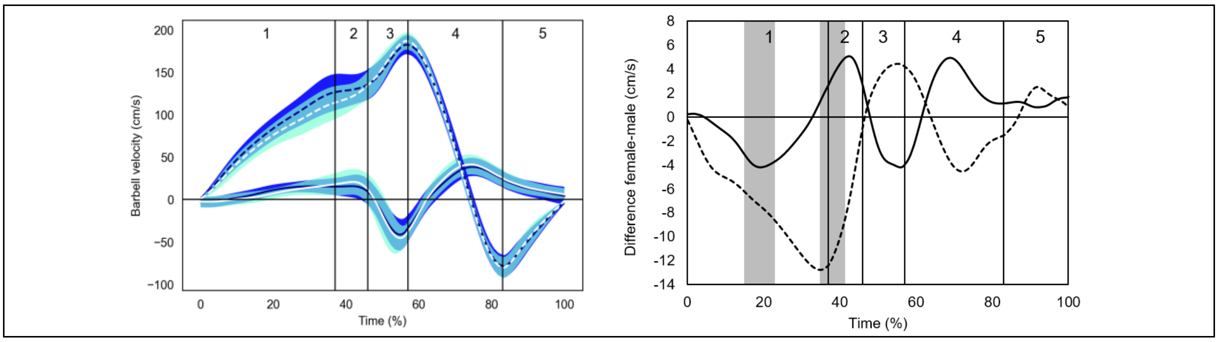

Figure 2: Left: Mean vertical (dashed lines) and horizontal (solid lines) barbell velocities with standard deviations for female (white) and male (blue) weightlifters. Right: Absolute mean differences for horizontal (solid line) and vertical (dashed line) barbell velocity. Grey shaded area represents significant difference of Hotelling's test. Lifting phases for the snatch are coded as: 1st pull (1), transition (2), 2nd pull (3), turnover (4), catch (5).

The regression analyses revealed positive correlations between body weight and barbell kinematics in female and male weightlifters. Larger correlations of horizontal barbell displacement and velocity have been determined for women, while almost identical correlations were observed for both sexes for vertical barbell displacement and velocity (Figure 3).

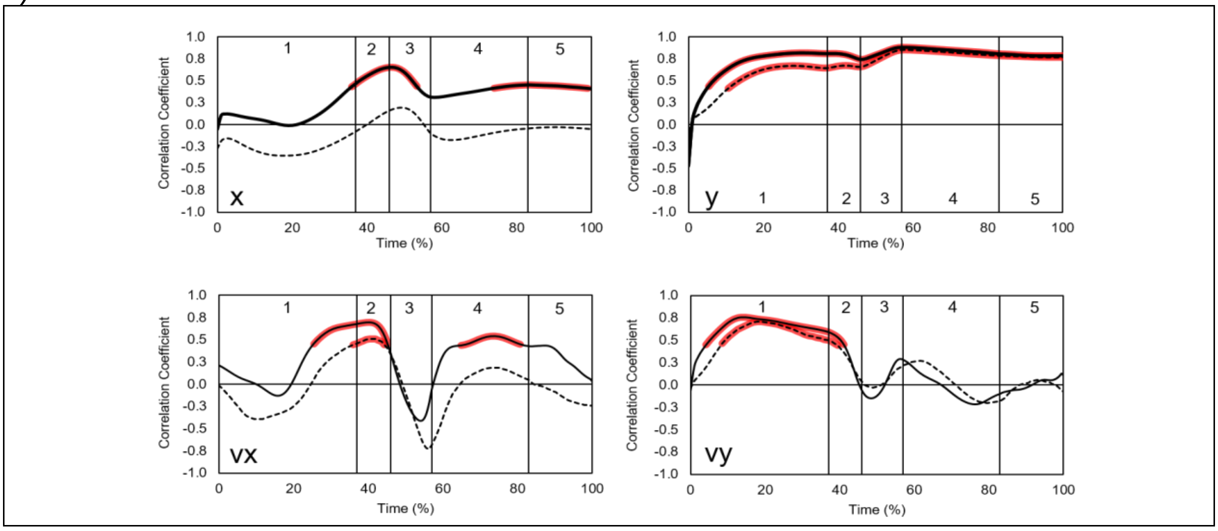

Figure 3: Correlations of barbell displacement (upper row) and velocity (lower row) with body weight for female (solid lines) and male (dashed lines) weightlifters. Red highlighted sections represent statistical significance. Lifting phases for the snatch are coded as: 1st pull (1), transition (2), 2nd pull (3), turnover (4), catch (5).

DISCUSSION: This study aimed to analyse barbell kinematics of the snatch in female and male international weightlifters to highlight sex differences. Contrary to our hypothesis, female weightlifters did not show significantly higher maximal vertical barbell velocity or larger maximal vertical displacement. However, significant differences in mean vertical barbell kinematics can be detected during the 1st pull and at the beginning of the transition. Notably, the mean barbell trajectory and barbell velocity of the present international female and male weightlifters display almost identical patterns. The discrepancies between the results of previous studies dating back more than 12 years and the present study may be due to the time factor and the ongoing technical skill development of female weightlifters. The absence of mean differences in maximal vertical barbell velocity suggests that female weightlifters are snatching more efficiently since lower maximal vertical barbell velocity during the 2nd pull is associated with better technical skills (Sandau & Granacher, 2023). However, the main cause of smaller vertical barbell displacement during the 1st pull in females can be attributed to their smaller body height compared to males (Lippmann & Sandau, 2012). As the 1st pull is more strength-related than other lifting phases (Ho et al., 2014), the trend to lower vertical barbell velocity during the 1st pull can be attributed to lower strength abilities in female athletes. In addition to lower strength abilities, the smaller body height in female weightlifters consequently results in smaller joint angles in the lower extremities during the start, which further affects muscle length and force production capacities. Therefore, strengthening the 1st pull may be of high importance for female weightlifters in lower body weight categories. In this context, in agreement with our hypothesis, barbell kinematics positively correlate with body weight (and thus body height). The dependence of barbell kinematics on body weight can explain the large variability in kinematic parameters and could account for the non-significant sex differences in vertical barbell kinematics despite large mean differences.

CONCLUSION: From a barbell kinematics perspective, on average, recent female weightlifters do not snatch much differently than their male counterparts. This observation may be an indication of the professionalization of female weightlifters in the last decades. The tendency to lower vertical barbell velocity at the end of the 1st pull in women indicates that strengthening the 1st pull may have the potential to increase the snatch performance of female weightlifters.

REFERENCES:

Akkuş, H. (2012, Apr). Kinematic analysis of the snatch lift with elite female weightlifters during the 2010 World Weightlifting Championship. *J Strength Cond Res, 26*(4), 897-905. https://doi.org/10.1519/JSC.0b013e31822e5945

Cunanan, A. J., Hornsby, W. G., South, M. A., Ushakova, K. P., Mizuguchi, S., Sato, K., Pierce, K. C., & Stone, M. H. (2020, Aug 25). Survey of barbell trajectory and kinematics of the snatch lift from the 2015 world and 2017 Pan-American weightlifting championships. *Sports, 8*(9). https://doi.org/10.3390/sports8090118

Gourgoulis, V., Aggeloussis, N., Antoniou, P., Christoforidis, C., Mavromatis, G., & Garas, A. (2002, Aug). Comparative 3-dimensional kinematic analysis of the snatch technique in elite male and female greek weightlifters. *J Strength Cond Res, 16*(3), 359-366.

Harbili, E. (2012). A gender-based kinematic and kinetic analysis of the snatch lift in elite weightlifters in 69-kg category. *Journal of Sports Sci Med, 11*(1), 162-169.

Helwig, N. E., Hong, S., Hsiao-Wecksler, E. T., & Polk, J. D. (2011). Methods to temporally align gait cycle data. *J Biomech, 44*(3), 561-566. https://doi.org/10.1016/j.jbiomech.2010.09.015

Ho, L. K., Lorenzen, C., Wilson, C. J., Saunders, J. E., & Williams, M. D. (2014). Reviewing current knowledge in snatch performance and technique: the need for future directions in applied research. *J Strength Cond Res, 28*(2), 574-586.

Isaka, T., Okada, J., & Funato, K. (1996). Kinematic analysis of the barbell during the snatch movement in elite Asian weightlifters. *J Appl Biomech, 12*(4), 508-516. https://doi.org/10.1123/jab.12.4.508

Kipp, K., Comfort, P., & Suchomel, T. J. (2021, Sep 1). Comparing Biomechanical Time Series Data During the Hang-Power Clean and Jump Shrug. *J Strength Cond Res, 35*(9), 2389-2396. https://doi.org/10.1519/jsc.0000000000003154

Kipp, K., & Harris, C. (2014). Patterns of barbell acceleration during the snatch in weightlifting competition. *J Sports Sci, 33*(14), 1467-1471. https://doi.org/10.1080/02640414.2014.992035

Lippmann, J., & Sandau, I. (2012). Internationale und nationale Entwicklungstendenzen im Gewichtheben bis zu den Olympischen Spielen 2012. *Zeitschr Ang Trainingswiss, 19*(2), 187-204.

Okada, J., Iijima, K., Fukunaga, T., Kikuchi, T., & Kato, K. (2009). Kinematic analysis of the snatch technique used by Japanese and internationale female weightlifters at the 2006 junior world championchip. *Int J Sport Health Sci, 6*, 194-202.

Pataky, T. C. (2012). One-dimensional statistical parametric mapping in Python. *Comput Methods Biomech Biomed Engin, 15*(3), 295-301. https://doi.org/10.1080/10255842.2010.527837

Sandau, I., & Granacher, U. (2023). Optimal barbell force-velocity profiles can contribute to maximize weightlifting performance. *PLoS One, 18*(8), e0290275. https://doi.org/10.1371/journal.pone.0290275

Sandau, I., Jentsch, H., & Bunk, M. (2019). Realanalyzer HD - A real-time barbell tracking software for weightlifting. *EWF Sci Mag, 5*(3), 14-23.

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