EFFECTS OF SHANK MASS MANIPULATION ON LANDING AND TAKEOFF TECHNIQUES IN SPRINTING

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The purpose of this study was to determine the effects of shank mass manipulation on landing and takeoff techniques in maximal speed sprinting. Sixteen male sprinters sprinted without and with an additional 15% shank mass attached around the center of mass of shank. Kinematic data in maximal speed phase were collected, reduced, and analyzed using linear regression analyses with category variable and paired t-tests. The sprinting speed and knee joint angle at landing were significantly decreased with 15% shank mass manipulation. The 15% shank mass manipulation did not significantly affect the relationships of sprinting speed with critical linear and angular kinematics at landing and takeoff of maximal speed sprinting. These results suggest that the additional 15% shank mass does not change landing and takeoff sprinting techniques of male sprinters in maximal speed sprinting.

KEYWORDS: well-trained athlete, resistance training, maximal speed sprinting

INTRODUCTION: Improving and keeping of maximum sprinting speed is a primary goal of sports training across almost all land-based sports. Mass manipulation training is a commonly used resistance sprinting training method to enhance maximum sprinting speed (Clark, Stearne, Walts, & Miller, 2010), in which athletes sprinting with extra masses attached to body segments (Bennett, Sayers, & Burkett, 2009). However, a major concern is that the mass manipulation training method might change the athletes' sprinting techniques when the athletes are sprinting (Alcaraz, Palao, Elvira, & Linthorne, 2008). Landing and takeoff sprinting techniques are two important techniques for better maximal speed sprinting (Hay, 1993). Understanding the effects of mass manipulation training on sprinting techniques is important for appropriate application of this method in sprinting training to improve performance. The purpose of this study was to determine the effects of attaching an additional 15% of the shank mass on the shank (shank mass manipulation) on landing and takeoff techniques in maximal speed sprinting.

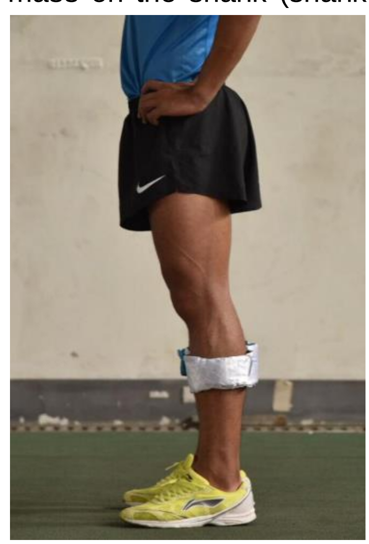

Figure 1. Attachment of additional mass.

METHODS: Sixteen well-trained male sprinters (age 21 ± 2 years; standing height 1.76 ± 0.04 m; body mass 67.41 ± 5.72 kg) volunteered to participate in this study. Mean 100 m race time was 10.97 ± 0.34 s. All participants were free of lower extremity musculoskeletal injuries for at least six months before participated in this study. All participants enrolled in the study were blind to the hypotheses of this study. The use of human subjects in this study was approved by the Internal Review Board of Shanghai University of Sport. Each participant signed a written consent before any data were collected. Each participant was instructed to sprint under two conditions: without shank mass manipulation and with shank mass manipulation of 15% of the shank mass attached around the center of mass of shank (Figure 1), which was 5% heavier than former study (Bennett et al., 2009). Shank mass was assumed to be 3.67% of body mass, while shank center of mass was assumed to be on the longitudinal axes of the shank and 39.3% of shank length away from the knee joint center (Zheng, Jia, & Gao, 2007). In each condition, the participant was asked to sprint from a starting line 40 m away from center of data collection area (2 meters wide X 5 meters long) to ensure that the participant was sprinting through the data collection area with maximum sprinting speed, and continue sprinting at the maximal speed for 60 m.

Fifty-two reflective markers were placed on participant. 2-D trajectories of reflective markers were recorded by 12 infrared cameras at a sample rate of 200 Hz. Raw 3-D trajectories of reflective markers were filtered at an optimal cutoff frequency of 13 Hz (Yu, 1989). One successful trial was obtained for condition for each participant. A successful trial was defined as a trial in which the participant did not adjust steps before sprinting into the data collection area, and had no markers lost before sprinting into and while sprinting through the data collection area.

A sprinting step cycle was defined as the duration between two consecutive landings, which was calculated as the duration between supporting foot landing and swing foot landing. The instant of landing was defined as the first time when a contact between swing foot and ground was observed, which was calculated as the vertical acceleration of the big toe marker of swing foot bigger than $0m/s^2$. The instant of takeoff was defined as the last time when a contact between supporting foot and ground was observed, which was calculated as the vertical acceleration of the big toe marker of supporting foot equals to $0m/s^2$. Sprinting speed was defined as mean anterior-posterior velocity of body center of mass for a step cycle. Landing distance was defined as the horizontal distance between the toe of the landing foot and the whole body center of mass at the instant of landing. Landing height was defined as the height of whole body center of mass at the instant of landing. Takeoff distance was defined as the horizontal distance between the toe of the takeoff foot and the whole body center of mass at the instant of takeoff. Takeoff height was defined as the height of body center of mass at the instant of takeoff. Landing and takeoff distances and heights were normalized to the sprinter's standing height. Hip flexion/extension angle, knee flexion/extension angle, and ankle dorsal/plantar flexion angle at landing and takeoff were calculated as the angle between the longitudinal axes of thigh and pelvis, shank and thigh, and foot and shank at instant of landing and takeoff, respectively.

Paired t-test was performed to compare each kinematic variable between sprinting conditions. Linear regression analyses with category variable were performed to determine the relationship of sprinting speed with each kinematic variable, and sprinting condition. The regression model in these analyses was $y = a_0 + a_1x_1 + a_2x_2 + a_3x_1x_2 + e$, where x_1 was kinematics variables, x_2 was the category variable representing sprinting condition ($x_2 = 0$ for sprinting without shank mass manipulation; $x_2 = 1$ for sprinting with shank mass manipulation), a_0 was intercept, a_1 to a_3 were regression coefficients, and e was error. A Type I error rate lower than 0.05 was considered as an indication of statistical significance.

RESULTS: The sprinting speed was decreased ($P < 0.01$), knee joint angle ($P = 0.03$) at the landing was significantly increased with shank mass manipulation (Table 1). Landing distance, takeoff distance, takeoff height, knee joint angle and ankle joint angle at the takeoff were significantly correlated to sprinting speed ($P \le 0.05$, $R^2 \ge 0.12$) (Table 1). Shank mass manipulation did not significantly affect the relationship of sprinting speed and these variables ($P \ge 0.16$) (Table 1).

Table 1: Comparison of kinematics between sprinting conditions.

Variable	Sprinting Conditions: Without shank mass manipulation	Sprinting Conditions: With 15% shank mass manipulation	P-value	Correlation with Sprinting Speed: R^2	Correlation with Sprinting Speed: P-value	Correlation with Sprinting: R^2	Correlation with Sprinting: P-value
Sprinting speed (m/s)	9.43 ± 0.49	9.22 ± 0.54	0.01	---	---	---	---
Landing distance (BH)	0.19 ± 0.03	0.20 ± 0.03	0.12	0.19	0.01	0.21	0.45
Landing height (BH)	0.58 ± 0.02	0.58 ± 0.01	0.85	0.14	0.90	0.04	0.25
Takeoff distance (BH)	0.27 ± 0.06	0.26 ± 0.06	0.42	0.17	0.02	0.23	0.16
Takeoff height (BH)	0.57 ± 0.01	0.57 ± 0.01	1.00	0.22	0.01	0.26	0.20
Hip flexion (+)/extension (-) angle at landing (°)	57.6 ± 8.5	58.7 ± 9.1	0.41	0.06	0.86	0.04	0.25
Knee flexion (+)/extension (-) angle at landing (°)	33.4 ± 5.9	31.7 ± 6.1	0.03	0.07	0.78	0.07	0.59
Ankle dorsal (+)/plantar (-) flexion angle at landing (°)	12.38 ± 5.00	13.06 ± 5.49	0.35	0.06	0.17	0.11	0.76
Hip flexion (+)/extension (-) angle at takeoff (°)	-8.5 ± 12.2	-9.9 ± 14.3	0.40	0.09	0.09	0.15	0.20
Knee flexion (+)/extension (-) angle at takeoff (°)	27.5 ± 11.4	27.0 ± 11.4	0.80	0.18	0.02	0.22	0.94
Ankle dorsal (+)/plantar (-) flexion angle at takeoff (°)	-26.93 ± 16.45	-23.50 ± 17.09	0.24	0.12	0.05	0.16	0.24

DISCUSSION: Mass manipulation as a commonly used resistance training method, appears to be more effective in improving maximum sprinting speed in comparison to traditional weight training (Clark et al., 2010). The resistance training is applied to the athletes in actual sprinting to develop strength specifically needed for sprinting. Whether it changed sprinting technique or not was a major concern in training. The purpose of this study was to determine the effects of an additional 15% shank mass manipulation on sprinting techniques in maximal speed sprinting.

The results of this study showed that, although shank mass manipulation resulted in a significant decrease in sprinting speed, it did not significantly affect the relationship of sprinting speed with selected kinematic variables at landing and takeoff. The changes in landing and takeoff techniques in maximal speed sprinting with shank mass manipulation were essentially in equivalent to sprinting at a lower speed without shank mass manipulation. These results in this study are consistent with several previous studies (Alcaraz et al., 2008; Bennett et al., 2009), which reported that the sprinting speed significantly decreased in sprinting with mass manipulation compared to sprinting without mass manipulation. As our results showed, mass manipulation did not change the relationships of sprinting speed with technical parameters. Therefore, differences of techniques could not be directly attributed to mass manipulation, but due to decreased technical demands for decreased sprinting speed resulting from mass manipulation. The results of this study showed that, shank mass manipulation resulted in a significant decrease in knee flexion angle at landing, which indicate knee extension increased at landing in this study. Shank mass manipulation did not significantly affect the relationship of sprinting speed with knee flexion angle at landing, which indicate the decrease in the knee flexion angle at landing was likely due to other results of kinematic and kinetic variable changes, not shank mass manipulation in this study. These results combined together suggest the decreased in knee flexion angle at landing was actually a technical response to the decreased sprinting speed, instead of a response to shank mass manipulation. Further, the results of this study also showed that knee flexion angle at the landing was not significantly correlated to the sprinting speed, which indicate that the decrease of knee flexion angle at landing did not affect sprinting speed in this study. The result of this study is consistent with a previous study (Mero, Komi, & Gregor, 1992), which reported that knee flexion angle at landing was not correlated to sprinting speed. On the other hand, the result of this study is inconsistent with another previous study (Caekenberghe, Segers, Aerts, Willems, & De, 2013), which reported that the knee flexion angles at landing was negative correlated to sprinting speed. The most likely explanation for this discrepancy between the current study and literature is the different levels of participants and different sprinting speed.

Shank mass manipulation did not result in significant changes in lower extremity joint angles at takeoff. The results of this study also showed that shank mass manipulation did not significantly affect the relationship of sprinting speed with these three variables. Although lower extremity joint angle at takeoff would affect ground reaction force at takeoff (Mann, 1981), stance time (Mann, 1985; Mann & Herman, 1985), forward swing velocity of swing leg (Wang, Luo, & Qiu, 1997), takeoff distance and flight distance (Hay, 1993), then affect the sprinting speed in maximal speed sprinting. But the results in this study indicate that the takeoff technique was not changed with shank mass manipulation. Therefore, the takeoff technique was not affected by 15% shank mass manipulation. Knee flexion angle and ankle plantar flexion angle at takeoff were significantly correlated to the sprinting speed. The results in this study are consistent with previous studies (Mann, 1981), which reported knee flexion angle and ankle plantar flexion angle at takeoff were correlated to sprinting speed. On the other hand, the results in this study are inconsistent with previous studies, which reported that hip extension angle was correlated to sprinting speed. The most likely explanation of this discrepancy between the current study and literature is the levels of participants.

CONCLUSION: The results of this study warrant the following conclusions: (1) 15% shank mass manipulation resulted in a significant decrease in maximal speed of sprinting; (2) 15% shank mass manipulation did not result in significant decreases in landing distance and height, takeoff distance and height, and did not alter the relationships of sprinting speed with these parameters; (3) 15% shank mass manipulation resulted in significant changes in lower extremity joint angle at landing, while lower extremity joint angles at landing were not correlated to the speed of sprinting. (4) 15% shank mass manipulation did not result in significant changes in lower extremity joint angles at takeoff, and did not alter the relationships of sprinting speed with these parameters.

PRACTICAL IMPLICATIONS: 15% shank mass manipulation does not affect critical techniques in maximal speed sprinting. Sprinting speed should be considered in mass manipulation training.

REFERENCES

Alcaraz, P. E., Palao, J. M., Elvira, J. L., & Linthorne, N. P. (2008). Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *J Strength Cond Res, 22*(3), 890.

Bennett, J. P., Sayers, M. G., & Burkett, B. J. (2009). The impact of lower extremity mass and inertia manipulation on sprint kinematics. *J Strength Cond Res*, 23(9), 2542-2547.

Caekenberghe, I. V., Segers, V., Aerts, P., Willems, P., & De, C. D. (2013). Joint kinematics and kinetics of overground accelerated running versus running on an accelerated treadmill. *J R Soc, 10*(84), 20130222.

Clark, K. P., Stearne, D. J., Walts, C. T., & Miller, A. D. (2010). The Longitudinal Effects of Resisted Sprint Training Using Weighted Sleds Vs. Weighted Vests. *J Strength Cond Res, 24(*12), 3287-3295.

Hay, J. G. (1993). THE BIOMECHANICS OF SPORTS TECHNIQUES (4th Ed.): PRENTICE-HALL, INC.

Mann, R. V. (1981). A kinetic analysis of sprinting. *Med Sci Sports Exerc,* 13(5), 325-328.

Mann, R. V. (1985). Biomechanical analysis of the elite sprinter and hurdler. The Elite Athlete, 23, 43-80.

Mann, R. V., & Herman, J. (1985). Kinematic Analysis of Olympic Sprint Performance: Men's 200 Meters. Academic Dissertation of Hong Kong University, 1(2), 151-162.

Mero, A., Komi, P. V., & Gregor, R. J. (1992). Biomechanics of sprint running. A review. *Sports Med, 13*(6), 376.

Wang, Z. Q., Luo, Y. B., & Qiu, A. H. (1997). Review of new sprinting technique. J Wuhan Ins. of P.E.(3), 44-47.

Yu, B. (1989). Determination of the optimum cutoff frequency in the digital filter data smoothing procedure. *J Biomech, 22*(10), 988-988.

Zheng, X. Y., Jia, S. H., & Gao, Y. F. (2007). Modern Sports Biomechanics (2nd). Beijing, China: National Defense Industry Press.

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