BIOMECHANICAL ANALYSIS OF TIRE FLIPPING WITH TIRES OF DIFFERENT MASSES AND THEIR POTENTIAL SPECIFICITY TO SPRINTING

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This study compared the kinetics of tire flipping with different mass tires and sprinting to evaluate the potential specificity of this training stimulus. Subjects (N=15) performed tire flips with a 54.3 kg tire, a 102.1 kg tire, and sprinted on two large force platforms. Dependent variables included peak horizontal ground reaction force (HGRF), peak vertical GRF (VGRF), horizontal to vertical GRF ratio (H:V), and rate of vertical GRF development (VRFD). A RM ANOVA was used to analyze the data. Significant main effects were found for all dependent variables ($p \leq 0.03$). Post-hoc analysis showed that the tires were different ($p \leq 0.04$) for all dependent variables except for VRFD ($p = 0.99$). Post-hoc analysis showed that the 54.3 kg tire was more similar to the kinetics of sprinting for HGRF, VGRF, and H:V. Only tire flipping with a lighter tire was similar to key kinetic parameters of sprinting.

KEYWORDS: strongman exercises, sprinting, acceleration

INTRODUCTION: Tire flipping is an exercise used during strongman competitions and has been recommended for inclusion in strength and conditioning programs (Bullock & Aipa, 2010). Training studies and acute research studies have evaluated select aspects of tire flipping.

Strongman exercise training has been compared to traditional resistance training, demonstrating no significant difference in outcome variables such as strength, power, and speed, between the training interventions (Winwood et al., 2015). Training with different sized tires has also been studied, demonstrating no differences in hand grip or bench press strength, horizontal power, agility, or sprint performance (Wong et al., 2020).

Acute evaluation of select aspects of tire flipping included the study of kinematics (Keogh, et al., 2010; McGill et al., 2009), electromyography (McGill et al., 2009), blood lactate (Keogh et al., 2010; Harris et al., 2016), heart rate (Keogh et al., 2010), expired gas analysis (Iskandar et al., 2017), and salivary testosterone (Harris et al., 2016). In these studies, tire flipping was one of several different strongman exercises assessed (McGill et al., 2009; Harris et al., 2016), strongman exercises were compared to traditional resistance exercises (Harris et al., 2016), only one tire was used in the analysis (Keogh et al., 2010), or combined training with tires and heavy ropes was assessed (Iskandar et al., 2017). Tire masses evaluated in the research included 43 kg (Wong et al., 2020), 74.2 kg (Iskandar et al., 2017), 104 kg (Wong et al., 2020), 220 kg (Harris et al., 2016), 232.1 kg (Keogh et al., 2010), and 309 kg (McGill et al., 2009).

No research assessed the kinetics associated with tire flipping, compared the kinetics of tires of different masses, or evaluated how tire flipping compares to other athletic events such as sprinting. As previously identified, while tire flipping would appear to be useful for training for athletic tasks, there is a lack of research on this topic (Bullock & Aipa, 2010). Therefore, the purpose of this study was to compare the kinetics of tire flipping with different mass tires and to compare the kinetics associated with tire flipping to sprinting, to evaluate the potential specificity of this training stimulus.

METHODS: Fifteen men (mean ± SD; age = 20.07 ± 1.3 years) volunteered for this study and provided informed consent. Subjects included NCAA Division III athletes who played football, baseball, and volleyball, and had 2.6 ± 1.1 years of college sports experience. All subjects provided written informed consent, and this study was approved by the Institutional Review Board.

Subjects participated in a general, dynamic, and an activity specific warm-up prior to the testing session. Subjects also practiced in each of the test conditions which included: tire flipping with a 54.3 kg tire (Rear Farm/Summit, Tire Alliance Group, Florham Park, NJ, USA) (54kg), a 102.1

kg tire (Power Mark 2000, Kelly Springfield, Akron, Ohio, USA) (102kg), and the standing start sprint (SSS). Subjects were randomly tested with two trials in each of the test conditions.
Data were obtained from two flush to the floor-mounted force platforms (Accupower, Advanced Mechanical Technology, Inc., Watertown, MA, USA) deployed in series. The tire was placed spanning both platforms. The subject began the tire flip on one platform. As soon as the subject began to vertically displace the tire, the entire mass was on the second of two force platforms in the series (Figures 1-2). The tire flipping technique was consistent with previous descriptions of the exercise (Bullock & Aipa, 2010). For the SSS, the subject began off of the platform but within two cm of the edge of the first force platform and sprinted across the force platforms (Figure 3) from a stationary standing starting position, which allowed the assessment of the first three steps of the sprint. The force platforms were calibrated prior to the testing session. Data were acquired at 1000 Hz and analyzed in real time with proprietary software (BP 6001200, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA). Dependent variables included peak horizontal ground reaction force (HGRF), peak vertical GRF (VGRF), horizontal to vertical GRF ratio (H:V), and rate of vertical GRF development (VRFD). Data were acquired for the subject's propulsive phase for the 54kg, 102 kg, and for each of three steps, and the average of the three steps of the SSS.
Data were analyzed with statistical software (SPSS 28.0, International Business Machines Corporation, Armonk, New York) using a one-way ANOVA with repeated measures for the tire conditions and the sprint. Bonferroni adjusted pairwise comparisons were conducted when main effects were present to assess specific differences in the dependent variables between each of the test conditions. The trial-to-trial reliability of the dependent variables were assessed using average measures intraclass correlation coefficients (ICC) and coefficients of variation (CV). The ICC were found to be > .60 and CV less than 10.0; thus, the average values were used for further analyses. Assumptions for normality of statistics were tested and met. The *a priori* alpha level was set at $p \leq 0.05$.

Figures 1-3. Subject performing the tire flip with the 54.3 kg tire and sprinting (in their second stride) on the force platforms.

RESULTS: Significant main effects were found between conditions for all dependent variables. Data, main effects, and the post-hoc analyses are found in Tables 1-4. Average measure intraclass correlation coefficients for the dependent variables for each exercise test and load condition ranged from .74 to .99.

Table 1. Peak horizontal ground reaction force (N) for 54.3 kg tire flips (54kg), 102.1 kg tire flips (102kg), and the first step (S1), second step (S2), third step (S3), and the mean of all steps (S1-3) of sprinting. Data are mean ± SD. (N=15).

54kg	102kg	Step(s)	ME	Post-Hoc Tires	Post-Hoc Tires & Steps
337.25±107.52	229.25±119.88	(S1) 334.21±113.56	*p*=0.01	*p*=0.003	S1 & 54kg (*p*=0.089), S1 & 102kg (*p*=0.001)
337.25±107.52	229.25±119.88	(S2) 313.13±138.53	*p*=0.02	*p*=0.003	S2 & 54Kg (*p*=0.98), S2 and 102kg (*p*=0.17)
337.25±107.52	229.25±119.88	(S3) 618.71±91.04	*p*=0.001	*p*=0.003	S3 & 54kg (*p*=0.001), S3 & 102kg (*p*=0.001)
337.25±107.52	229.25±119.88	(S1-3) 422.02± 95.24	*p*=0.001	*p*=0.003	S1-3 & 54kg (*p*=0.09), S1-3 & 102kg (*p*=0.001)

ME = Main effects (*p* value) of the RM ANOVA; Post Hoc-Tires and Post Hoc Tires & Steps represents the results of the Bonferroni post-hoc analysis (*p* value) which are depicted based in the differences between 54kg and 102kg test conditions as well as between the 54kg tire, 102kg tire, and the sprint steps.

Table 2. Peak vertical ground reaction force (N) for 54.3 kg tire flips (54kg), 102.1 kg tire flips (102kg), and the first step (S1), second step (S2), third step (S3), and the mean of all steps (S1-3) of sprinting. Data are mean ± SD. (N=15).

54kg	102kg	Step(s)	ME	Post-Hoc Tires	Post-Hoc Tires & Steps
1539.08±233.00	1669.27±200.92	(S1) 1440.15 ±157.74	*p*=0.001	*p*=0.04	S1 & 54kg (*p*=0.06), S1 & 102kg (*p*=0.001)
1539.08±233.00	1669.27±200.92	(S2) 1437.02±242.99	*p*=0.001	*p*=0.04	S2 & 54Kg (*p*=0.06), S2 & 102kg (*p*=0.001)
1539.08±233.00	1669.27±200.92	(S3) 1582.88±272.66	*p*=0.03	*p*=0.04	S3 & 54kg (*p*=0.99), S3 & 102kg (*p*=0.37)
1539.08±233.00	1669.27±200.92	(S1-3)1489.69±206.59	*p*=0.001	*p*=0.04	S1-3 & 54kg (*p*=0.38), S1-3 & 102kg (*p*=0.001)

ME = Main effects (*p* value) of the RM ANOVA; Post Hoc-Tires and Post Hoc Tires & Steps represents the results of the Bonferroni post-hoc analysis (*p* value) which are depicted based in the differences between 54kg and 102kg test conditions as well as between the 54kg tire, 102kg tire, and the sprint steps.

Table 3. Horizontal to vertical peak ground reaction force ratio for 54.3 kg tire flips (54kg), 102.1 kg tire flips (102kg), and the first step (S1), second step (S2), third step (S3), and the mean of all steps (S1-3) of sprinting. Data are mean ± SD. (N=15).

54kg	102kg	Step(s)	ME	Post-Hoc Tires	Post-Hoc Tires & Steps
0.22 ± 0.06	0.14 ± 0.08	(S1) 0.23±0.07	*p*=0.004	*p*=0.006	S1 & 54kg (*p*=0.99), S1 & 102kg (*p*=0.02)
0.22 ± 0.06	0.14 ± 0.08	(S2) 0.22±0.09	*p*=0.02	*p*=0.006	S2 & 54Kg (*p*=0.99), S2 and 102kg (*p*=0.04)
0.22 ± 0.06	0.14 ± 0.08	(S3) 0.40±0.03	*p*=0.001	*p*=0.006	S3 & 54kg (*p*=0.001), S3 & 102kg (*p*=0.001)
0.22 ± 0.06	0.14 ± 0.08	(S1-3) 0.28±0.06	*p*=0.001	*p*=0.006	S1-3 & 54kg (*p*=0.09), S1-3 & 102kg (*p*=0.006)

ME = Main effects (*p* value) of the RM ANOVA; Post Hoc-Tires and Post Hoc Tires & Steps represents the results of the Bonferroni post-hoc analysis (*p* value) which are depicted based in the differences between 54kg and 102kg test conditions as well as between 54kg tire, 102kg tire, and the sprint steps.

Table 4. Vertical rate of force development (N▪sec^{-1}) for 54.3 kg tire flips (54kg), 102.1 kg tire flips (102kg), and the first step (S1), second step (S2), third step (S3), and the mean of all steps (S1-3) of sprinting. Data are mean ± SD. (N=15).

54kg	102kg	Step(s)	ME	Post-Hoc Tires	Post-Hoc Tires & Steps
2839.95±1794.61	2818.70±1983.75	(S1)12,942.98±2094.93	*p*=0.001	*p*=0.99	S1 & 54kg (*p*=0.001), S1 & 102kg (*p*=0.001)
2839.95±1794.61	2818.70±1983.75	(S2)11,484.11±3280.18	*p*=0.001	*p*=0.99	S2 & 54Kg (*p*=0.001), S2 and 102kg (*p*=0.001)
2839.95±1794.61	2818.70±1983.75	(S3)13728.84±3205.49	*p*=0.001	*p*=0.99	S3 & 54kg (*p*=0.001), S3 & 102kg (*p*=0.001)
2839.95±1794.61	2818.70±1983.75	(S1-3)12718.01±2590.08	*p*=0.001	*p*=0.99	S1-3 & 54kg (*p*=0.001), S1-3 & 102kg (*p*=0.001)

ME = Main effects (*p* value) of the RM ANOVA; Post Hoc Tires and Post Hoc Tires & Steps represents the results of the Bonferroni post-hoc analysis (*p* value) which are depicted based in the differences between 54kg and 102kg test conditions as well as between 54kg tire, 102kg tire, and the sprint steps.

DISCUSSION: The current study is the first to evaluate the kinetic differences between tire flipping with different mass tires and the first to assess the potential specificity of tire flipping to the early acceleration phase of sprinting. Previous publications noted the absence of research on this topic (Bullock & Aipa, 2010).

The present study shows that based on the variables assessed, there are significant differences between tires of different masses. Performing the tire flip with the lighter tire resulted in approximately 47% and 57% more HGRF and H:V, respectively. Performing the tire flip with the heavier tire resulted in 8.4% more VGRF. Thus, tires of different masses produce unique training stimuli. Similar specificity of other forms of horizontal compared to vertical power training has been recently reviewed (Moran et al., 2021).

The HGRF between the 54.3 kg tire and the kinetics of the sprint were not significantly different for the first two steps of the sprint or for the mean of all the steps. In fact, the mean HGRF values were only between 0.08% to 7.1% different between the 54.3 kg tire and the first and second step of the sprint, respectively. Thus, the horizontal kinetics of flipping the lighter tire are very similar to that of sprinting. No previous tire flipping research evaluated these issues. However, other forms of training, such as the horizontal hang clean produces similar mean horizontal forces, which were also similar to sprinting (Gold et al., 2020). In the present study, the VGRF for each step, the average of all the steps of sprinting, and the H:V were more similar to tire flipping with the 54.3 kg tire than the 102.1 kg tire. The mean H:V associated with tire flipping with the lighter tire was greater than the mean H:V found with other horizontally directed exercises (Gold, et al., 2020). Thus, in the present study, the lighter tire offered a training stimulus that was more like sprinting than the heavy tire. The VRFD produced while flipping either tire was substantially higher than those produced during sprinting, as shown with exercise such as the horizontal hang clean (Gold et al., 2020).

While the present study demonstrates acute differences in the kinetics and potential training specificity of tire flipping, training studies showed that training with heavy compared to light tires did not result in between group differences in six repetition maximum bench press, hand grip, jumping, and agility tests (Wong et al., 2020).

Training with lighter tires offers a better acute training stimulus for activities that require horizontal force development such as sprinting, whereas heavier tires may be better for training for activities that require vertical force production. Previous reports (Bullock & Aipa, 2010) which suggested that tire flips, and their concomitant triple extension, are likely useful for developing athletic abilities such as sprinting, appear to be validated in part, based on the results of this study. The findings of the present study, including the use of lighter tires for greater horizontal force development are consistent with the idea that training with horizontal power exercises is likely to be more optimal at enhancing horizontal performance for sport (Moran et al., 2021).

Study limitations include the assessment of subject kinetics which were initially based on a bilateral stance for the tire flipping conditions and based on unilateral foot contacts for sprinting. Additionally, the authors acknowledge that comparable GRF may result in differing joint and biomaterial force manifestations.

CONCLUSION: During the tire flip exercise, lighter tires offer a superior H-GRF development stimuli and a better H:V, which is more similar to sprinting. The heavier tire produced a larger VGRF, though not similar to sprinting. Surprisingly, the VRFD of each tire was similar to the other. Athletes and those who train them should use lighter tires of a size similar to that used in this study to best match the kinetic demands associated with the acceleration phase of sprinting.

REFERENCES:

Bullock, J., & Aipa, D.M. (2010). Coaching considerations for the tire flip. *Strength and Conditioning Journal,* 32(5): 75-78.

Gold, M.E., Duffin, G.T., Shevalier, J.R., Stockero, A.M., Primas, N.H., & Ebben, W.P. (2020).
Kinetic and sex-based analysis of the traditional and horizontal hang clean. *ISBS Proceedings Archive*: Vol. 38: Iss. 1, Article 8.

Harris, N.K., Woulfe, C.J., Wood, M.R., Dulson, D.K., Gluchowski, A.K. & Keogh, J.B. (2016). Acute physiological responses to strongman training compared to traditional strength training. *Journal of Strength and Conditioning Research,* 30(5): 1397-1408.

Iskandar, M.M., Mohamad, N.I., Othman, S. & Nadzalan, A.M. (2017). Metabolic cost during tyre and rope functional training. *Journal of Fundamental and Applied Sciences,* 9(6S): 1050-1062.

Keogh, J.W.L., Payne, A.L., Anderson, B.B. & Atkins, P.J. (2010). A brief description of the biomechanics and physiology of a strongman event: The tire flip. *Journal of Strength and Conditioning Research,* 24(5): 1223-1228.

McGill, S.M., McDermott, A. & Fenwick, C.M.J. (2009) Comparison of different strongman events: Trunk muscle activation and lumbar spine motion, load, and stiffness. *Journal of Strength and Conditioning Research,* 23(4): 1148-1161.

Moran, J., Ramirez-Campillo R., Liew, B., Chaabene H., Behm D.G., García-Hermoso A., Izquierdo M. & U. Granacher (2021). Effects of vertically and horizontally orientated plyometric training on physical performance: A meta-analytical comparison. *Sports Medicine*, 51: 65–79.

Winwood, P.W., Cronin, J.B., Posthumus, L.R., Finlayson, S.J., Gill, N.D. & Keogh, J.W.L. (2015) Strongman vs. traditional resistance training effects on muscular function and performance. *Journal of Strength and Conditioning Research,* 29(2): 429-439.

Wong, D.P., Weldon, A., Ngo, J.K. (2020) Physical fitness improvements of 8-week light vs. heavy tyre flip training in young adults. *Biology of Sport,* 37(3): 203-210.