A BRIEF DESCRIPTION OF THE BIOMECHANICS AND PHYSIOLOGY OF A STRONGMAN EVENT: THE TIRE FLIP

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ABSTRACT

Keogh, JWL, Payne, AL, Anderson, BB, and Atkins, PJ. 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, 2010—The purpose of this study was to (a) characterize the temporal aspects of a popular strongman event, the tire flip; (b) gain some insight into the temporal factors that could distinguish the slowest and fastest flips; and (c) obtain preliminary data on the physiological stress of this exercise. Five resistance-trained subjects with experience in performing the tire flip gave informed consent to participate in this study. Each subject performed 2 sets of 6 tire flips with a 232-kg tire with 3 minutes of rest between sets. Temporal variables were obtained from video cameras positioned 10 m from the tire, perpendicular to the intended direction of the tire flip. Using the “stopwatch” function in Silicon Coach, the duration of each tire flip and that of the first pull, second pull, transition, and push phases were recorded. Physiological stress was estimated via heart rate and finger-prick blood lactate response. Independent T-tests revealed that the 2 faster subjects (0.38 ± 0.17 s) had significantly (p < 0.001) shorter second pull durations than the 3 slower subjects (1.49 ± 0.92 s). Paired T-tests revealed that the duration of the second pull for each subject’s fastest 3 trials (0.55 ± 0.35 s) were significantly (p = 0.007) less than their 3 slowest trials (1.69 ± 1.35 s). Relatively high heart rate (179 ± 8 bpm) and blood lactate (10.4 ± 1.3 mmol/L) values were found at the conclusion of the second set. Overall, the results of this study suggest that the duration of the second pull is a key determinant of tire flip performance and that this exercise provides relatively high degrees of physiological stress.

KEY WORDS: biomechanics, physiology, strongman, weight training

INTRODUCTION

Many strength and conditioning specialists are now beginning to incorporate strongman exercises into their regular conditioning programs (7,8,13,15). Strongman training might have some advantages over more traditional gym-based resistance training approaches because most human movements involve predominantly horizontal motion that occurs as a result of unilateral ground reaction force production. This contrasts with most traditional gym-based resistance training exercises that are vertical in nature and are performed with the 2 feet side by side. Although some practitioners advocated the use of lunges (11) and split-stance Olympic lifts (10) to offset some of these limitations of the traditional lifts, strongman exercises may be even more applicable because they often involve unstable and awkward resistances and would appear to require the production of high horizontal and vertical unilateral forces. The inclusion of strongman exercises such as the tire flip, sled pull, and yoke walk along with more common lifts such as the power clean, snatch, and squat may therefore further improve the performance and trunk stability of many athletic groups (8,12,15).

Of particular interest to this study is the tire flip. The tire flip requires a heavy tire (that is initially lying flat on the ground) to be flipped end-over-end as quickly as possible for a set distance or number of repetitions. The athlete will crouch down in front of the tire; grab the underside of the tire with a supinated grip approximately shoulder-width apart; and via forceful ankle, knee, hip and back extension attempt to flip the tire over. According to the recommendations of Havelka (6) and Hedrick (9), the tire flip may be composed of several phases: (a) initial pull; (b) second pull; (c) transition where the hands come off the tire; and (d) push, where the hands are repositioned on the tire so as to push the tire over.

Only 2 scientific studies appear to have been conducted on any of the strongman events. McGill et al (12) estimated the lower back loads and hip torque of 3 strongman performing a number of events such as the tire flip, Atlas stones, log lift, farmers walk, and yoke walk. These lifts were characterized by very high spine compression and shear forces, joint

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torques, and activity of many of the hip and trunk stabilizers (12). Berning et al (1) quantified the physiological demands of pushing and pulling a heavy car a distance of 400 m. The athletes reached 70% maximum oxygen output (VO_{2,max}) and 96% of maximum heart rate (HR), recorded a blood lactate (BLA) concentration of 16 mmol/L, and suffered an acute decrement in vertical jump height of 10 cm (17% of maximum) immediately after performing these tasks (1).

The purpose of this study was to (a) characterize the temporal aspects of the tire flip; (b) gain some insight into the temporal determinants of the tire flip by comparing the 3 fastest and slowest flips from each athlete; and (c) obtain preliminary data on the physiological stress imposed by the tire flip on the system via HR and BLA analysis. It was hypothesized that (a) the first and second pull of the tire flip would take longer to complete than other phases of the lift; (b) the duration of the second pull may be significantly longer in the slowest than fastest flips; and (c) the tire flip would produce high HR and moderately high BLA responses.

**METHODS**

**Experimental Approach to the Problem**

The present study used a cross-sectional approach to examine some biomechanical and physiological aspects of a strongman event, the tire flip. Specifically, this study focused on characterizing the temporal components (phases) of the tire flip and on gaining some insight into how the duration of these phases may relate to performance. Insight into the temporal determinants of tire flip performance was achieved via between- and within-subject comparisons. Changes in HR and BLA across multiple time-points were also examined.

**Subjects**

Five male subjects (25 ± 7 years, mass 90 ± 6 kg, height 180 ± 6 cm) participated in this study. All 5 had extensive resistance training experience, and 4 had competed in at least 1 strongman competition in which the tire flip was an event. Testing was conducted in the early- to mid-part of their competitive seasons. Subjects were informed of the experimental risks and signed an informed consent form prior to the investigation. The investigation was approved by an Institutional Review Board for the use of human subjects.

**Procedures**

Subjects completed a warm-up that consisted of several submaximal sets of deadlifts and power cleans for...
approximately 10 minutes. This was followed by 2–4 repetitions of the tire flip, performed in sets of 1–2 repetitions with moderate rest periods between each repetition or set. After completing their warm-up, the subjects performed 2 sets of 6 tire flips with the goal being to perform each repetition and set as quickly as possible.

Several methods could have been used to record the duration of the different phases of the tire flip. Although manual panning was considered (4,14), this would have resulted in substantial parallax error and a reduction in resolution. Accordingly, 3 stationary video cameras were used. After each flip, the subjects typically jogged to the other end of the tire so as to begin the next flip in the shortest period of time possible. This meant that all odd-numbered (#1, 3, and 5) flips went in 1 direction and all even-numbered (#2, 4, and 6) flips went in the opposite direction. A rest period of 3 minutes was given between the 2 sets, as is generally recommended for similar forms of training (3,6).

The tire had a mass of 232 kg, an external diameter of 1.50 m, and a height when lying on the ground of 0.52 m.

Biomechanical Measures. Temporal variables relating to tire flip performance were recorded by digital video cameras (Sony, PAL, New York, NY, USA; 50 Hz, 1/1000 s) that were positioned 0.8 m above the ground at a distance of 10 m to the closest edge of the tire. Camera 1 was 0.26 m past the tire with respect to the subject's starting position so to be equidistant to the tire's expected position across the odd- and even-numbered repetitions. The field of view of Camera 1 was approximately twice the width of the other cameras so that it could record all tire flips in each set and hence give a measure of total duration of each set of 6 repetitions. The other 2 cameras were positioned in line with the center of the tire in the starting position for the odd-numbered lifts (Camera 2) and its expected position after the first flip for the even-numbered lifts (Camera 3). Camera 2 and 3 were positioned on opposite sides of the tire so that they both focused on the right side of the subjects as they performed the odd- and even-numbered repetitions, respectively. Because of their smaller field of view and hence greater resolution, these 2 cameras were used to assess the temporal measures of each odd and even repetition, respectively. A schematic of the experimental set-up is presented in Figure 1.

Physiological Measures. Some indicators of the physiological stress involved with the tire flip were gained by monitoring the HR and BLA response of the subjects. Heart rate was monitored by a chest-mounted Polar 625X heart rate monitor (Polar, Auckland, New Zealand). The BLA response was determined via fingerprick. The capillary blood from the

<table>
<thead>
<tr>
<th>Table 1: Group results for the durations of selected phase of the tire flip.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (s) (n = 60)</td>
</tr>
<tr>
<td>Total flip time</td>
</tr>
<tr>
<td>First pull</td>
</tr>
<tr>
<td>Second pull</td>
</tr>
<tr>
<td>Transition</td>
</tr>
<tr>
<td>Push</td>
</tr>
</tbody>
</table>

All data are mean ± standard deviation.
Table 2. Durations for the selected phases of the tire flip for the faster 2 and slower 3 subjects.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Faster subjects (n = 24)</th>
<th>Slower subjects (n = 36)</th>
<th>p-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total flip time (s)</td>
<td>1.90 ± 0.33*</td>
<td>3.56 ± 0.91</td>
<td>&lt;0.001</td>
<td>-2.68</td>
</tr>
<tr>
<td>First pull (s)</td>
<td>0.71 ± 0.07*</td>
<td>0.77 ± 0.08</td>
<td>0.003</td>
<td>-0.83</td>
</tr>
<tr>
<td>Second pull (s)</td>
<td>0.36 ± 0.17*</td>
<td>1.49 ± 0.92</td>
<td>&lt;0.001</td>
<td>-2.03</td>
</tr>
<tr>
<td>Transition (s)</td>
<td>0.15 ± 0.03</td>
<td>0.15 ± 0.05</td>
<td>0.947</td>
<td>0.02</td>
</tr>
<tr>
<td>Push (s)</td>
<td>0.66 ± 0.17*</td>
<td>1.14 ± 0.33</td>
<td>&lt;0.001</td>
<td>-1.95</td>
</tr>
</tbody>
</table>

All data are mean ± standard deviation.
*Significant (p < 0.01) difference between the fastest and slowest flips.

Data Analysis. All video footage was analyzed using the "stopwatch" function of Silicon Coach Pro video analysis software (Dunedin, New Zealand). The "stopwatch" function allowed the determination of the time at which 5 key tire flip positions were reached. These positions were when the (a) tire was first lifted from the ground; (b) the tire first reached a height above the knee; (c) hands were initially taken off the tire; (d) hands were repositioned on the tire in readiness for the push; and (e) the tire reached a vertical position (Figure 3). From these 5 positions, total flip time along with the duration of the first pull, second pull, transition, and push phases were calculated. Definitions for these phases follow:

- **Total flip time**: Time from when the first part of the tire came off the ground to it rising to a vertical position (Figure 3A-E).
- **First pull**: Time from when the first part of the tire came off the ground to it rising vertically past the knee joint (Figure 3A, B).
- **Second pull**: Time taken from the end of the first pull (i.e., tire just above knee height) to when the hands are last taken off the tire prior to the push (Figure 3B, C).
- **Transition**: Time taken from when the hands last left the tire until the hands were repositioned on the tire prior to the push (Figure 3C, D).
- **Push**: Time from when the hands are last repositioned on the tire until the tire reaches the vertical position (Figure 3D, E).

Statistical Analyses
Standard descriptive statistics (means and standard deviations, \( \bar{x} \)) were calculated for all dependent variables. For the temporal variables, this was initially done across the entire 60 trials. An a priori, within-subject analysis was then performed using 2-tailed paired T-tests and effect sizes (ES) to compare the 3 slowest and fastest flips of each subject to examine the effect of fatigue on tire flip performance. Inspection of the group mean data revealed high variability in the duration of the second pull. Thus, a between-subject analysis using 2-tailed independent T-tests and ES was performed to compare the 2 subjects with a faster mean second pull than first pull duration to the remaining 3 subjects. Two-tailed paired T-tests and ES were also used to compare the change in HR and BLA from one time-point to the next (T0–T4). All statistical analyses were conducted using SPSS version 14.0 (Chicago, IL, USA) with significance set at \( p \leq 0.05 \). As described by Drinkwater et al (5) for sports science research, the magnitude of the effect was given by the ES, whereby ES

Table 3. Durations for the selected phases of the tire flip for the fastest 3 and slowest 3 flips per subject.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Fastest flips (n = 15)</th>
<th>Slowest flips (n = 15)</th>
<th>p-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total flip time (s)</td>
<td>2.26 ± 0.50*</td>
<td>3.72 ± 1.48</td>
<td>&lt;0.001</td>
<td>-1.48</td>
</tr>
<tr>
<td>First pull (s)</td>
<td>0.71 ± 0.07</td>
<td>0.76 ± 0.09</td>
<td>0.022</td>
<td>-0.67</td>
</tr>
<tr>
<td>Second pull (s)</td>
<td>0.55 ± 0.35*</td>
<td>1.69 ± 1.35</td>
<td>0.007</td>
<td>-1.34</td>
</tr>
<tr>
<td>Transition (s)</td>
<td>0.15 ± 0.04</td>
<td>0.17 ± 0.06</td>
<td>0.462</td>
<td>-0.27</td>
</tr>
<tr>
<td>Push (s)</td>
<td>0.85 ± 0.28</td>
<td>1.10 ± 0.50</td>
<td>0.066</td>
<td>-0.64</td>
</tr>
</tbody>
</table>

All data are mean ± standard deviation.
*Significant (p < 0.01) difference between the fastest and slowest flips.
†Significant (p < 0.05) difference between the fastest and slowest flips.

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those with a longer second pull (Table 2). These 2 faster subjects also had significantly shorter durations for the first pull and push phases than the slower subjects. The magnitude of these effects were much greater for the second pull (ES = −2.03) and the push phases (ES = −1.95) than the first pull (ES = −0.83).

Results for each subjects’ 3 fastest and 3 slowest flips are provided in Table 3. The fastest flips required significantly less time to complete the first and second pull than the slowest flips. However, the magnitude of these effects were much greater for the second pull (ES = −1.34) than the first pull (ES = −0.67).

The HR and BLa concentrations significantly increased over the 2 sets of tire flips. At the immediate postset time-points (T1 and T3), HR was significantly (p < 0.001) greater than all other time-points (T0, T2, and T4). For BLa response, all pairwise comparisons were significantly different (p = 0.001–0.017) with the exception of the 2 posttest (T3 vs. T4) values (p = 0.886). Effect size analyzes indicated that all of the significant changes in HR (ES = 4.28–4.83) and BLa (ES = 1.66–5.17) were large in magnitude (Figure 4).

<0.2 were defined as trivial, ES = 0.2–0.6 as small, ES = 0.6–1.2 as moderate, and ES >1.2 as large.

No power analysis was performed for this study because of the exploratory nature of this pilot study and the complete lack of data with which to conduct such an analysis. The test-retest reliability of all temporal measures was high (intraclass correlation coefficient = 0.96–0.99, coefficient of variance = 2.1–8.5%).

RESULTS

The temporal characteristics of selected phases of the tire flip are presented in Table 1. Inspection of the group mean data indicated that the transition phase had by far the shortest duration, with the second pull tending to be the longest.

Faster subjects (those with a shorter-duration second pull than first pull) had significantly quicker total flip times than

DISCUSSION

The results of this study provide the first normative data on the temporal aspects of any strongman event and give some insight into the temporal determinants of performance. Consistent with coaching recommendations (6,9), the subjects generally attempted to use a 4-phase movement pattern (first pull, second pull, transition, and push) to complete the tire flip. Of the 4 phases analyzed, the group mean results demonstrated that the second pull required the greatest time to complete, with the transition phase being by far the shortest. Such a result was somewhat consistent with our initial hypothesis, whereby we expected the first and second pull to be the phases of the longest duration. The first pull was expected to have a relatively long duration because the length of the tire’s resistance moment arm and hence its

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resistance torque was maximized when the tire was horizontal at the start of the first pull. Similarly, the duration of the second pull was also hypothesized to be relatively long because the resultant muscular torque in this phase was likely to be substantially less than that of the first pull as a result of changes in the primary agonists and to the force potential of these muscles as a result of the changes in the force-length and force-velocity relationships.

Greater variability in the overall group's results was observed for duration of the second pull than the other 3 phases. As a result of this variability, we inspected each subjects' mean results to see if this variability reflected a within- or between-subject effect. Results indicated a significant between-subject effect, with 2 of the subjects having a second pull duration that was shorter than that of the first pull and push phases. Of interest, these 2 subjects' total flip time was about half that of the other 3 subjects. Of further note, the increased time required by the slower subjects to complete the second pull (1.12 s) accounted for ~67% (1.66 s) of the between-group difference in the mean duration of each tire flip. A within-subject analysis involving each subjects' 3 fastest and slowest flips was also performed to examine the effect of fatigue on tire flip performance. Results indicated that the duration of the second pull was significantly longer in the slowest than fastest flips, with this accounting for ~78% (1.14 s) of the increase in total flip time (1.46 s). The results of these between- and within-subject analyses offer strong support for the proposition that the ability to complete the second pull as quickly as possible is the primary temporal determinant of tire flip performance.

The mean HR (~180 bpm) and BLA levels (~10.4 mmol/L−1) achieved at the conclusion of the 2 sets of 6 tire flips indicated that this resulted in a high degree of physiological stress. Such a result is somewhat similar to that found by Berning et al (1) for a 400-m car push/pull, whereby the subjects reached 70% VO2max and 96% of maximum HR and recorded a BLA concentration of 16 mmol/L−1. The duration of each set of 6 tire flips in the current study (23–51 s) was substantially shorter than the 6–8 minutes for the car push/pull (1). However, Berning et al (1) found that even after pushing/pulling the car 50 m (a distance that would have likely been completed in less than 1 minute), the subjects reached 44–49% VO2max and 90–92% of maximum HR. Collectively, these results lend credence to the view that strongman exercises can impose a very high physiological demand on the system. It is therefore not surprising that a number of conditioners advocate such exercises for increasing anaerobic conditioning and/or energy expenditure (7,8,13,15).

As a pilot study involving only 5 moderately experienced strongman athletes, the current study is not without its limitations. The first concern is the manner in which the tire flip was performed, whereby the subjects needed to alternate the direction of each flip based on the position of the camera. The second concern is that we only examined a small subset of important biomechanical (temporal) and physiological variables and that our temporal analysis only had a precision of 0.02 s.

Future research in this area should incorporate larger sample sizes, utilize athletes of more elite levels, examine a greater range of variables (e.g., joint kinematics, kinetics, and/or electromyography [12]), and determine the chronic effect of long-term strongman training on neuromuscular function.

**Practical Applications**

The results of this study provide some of the first experimental data on any of the strongman events. Because the between- and within-subject analyses indicated that the duration of the second pull was significantly longer in the slower tire flips, it appears that this phase is the most critical temporal determinant of performance. Strongman competitors and athletes who use this exercise in training should therefore concentrate on improving this phase of the lift. This may be best achieved by selecting training loads that allow the second pull to be performed explosively. The high HR and BLA responses seen in this study and in the literature for the car push/pull also suggest that strongman exercises might prove useful in improving anaerobic conditioning and for increasing energy expenditure.

**References**


