A TEMPORAL ANALYSIS OF A STRONGMAN EVENT: THE TYRE FLIP

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The purpose of this study was to characterize the temporal aspects of a strongman event, the tyre flip, as performed by five athletes. A two-dimensional video analysis of each athlete performing two sets of six flips of a 232 kg tyre was performed. Descriptive statistics were calculated for all trials as well as the fastest and slowest three repetitions for each athlete. The slowest section of the tyre flip occurred when the tyre was 30°-60° above horizontal. Comparison of the fastest vs slowest trials revealed that several temporal variables, particularly those occurring between 30°-60° above horizontal took significantly longer for the slowest than fastest repetitions. These results suggest that the ability to maintain a certain level of tyre angular velocity through the transition phase (30°-60° above horizontal) is a strong determinant of tyre flip performance.

KEYWORDS: Biomechanics, strongman, weight training.

INTRODUCTION:

Strength and conditioning specialists and coaches are always looking for ways to improve the performance of their athletes. As a result, many athletes perform weight training, plyometrics and various running drills to improve their muscular strength, power and endurance. With the increasing popularity of strongman competitions, many strength and condition specialists are now beginning to incorporate strongman exercises e.g. stone lifting, farmers walk, car pushing/pulling and the tyre flip into their regular conditioning programs (Hedrick, 2002; 2003; Waller *et al.*, 2003).

The tyre flip requires a heavy tyre (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 flips. In strongman competitions, the athlete who achieves this in the quickest time is the winner. The athlete will crouch down in front of the tyre in a crouched position, grab the underside of the tyre with a supinated grip approximately shoulder width apart and via forceful knee, hip and back extension will lift the tyre to a position whereby they are able to push it over. According to the coaching recommendations of Havelka (2004), the tyre flip may be composed of several phases, these being: 1) initial pull; 2) second pull; 3) transition where the hands come off the tyre; and 4) push, where the hands are repositioned on the tyre so to complete the flip by pushing the tyre over. If experimental data can support the view of Havelka (2004), the tyre flip would appear to have similar phasic and temporal characteristics to Olympic lifts such as the power clean and clean and jerk (Garhammer, 1984; Souza et al., 2002).

To the authors' knowledge, no biomechanical studies of any of the strongman events have yet been published, although Berning et al. (2007) has quantified the metabolic demands of pushing and pulling a car a distance of 400 m. Berning et al. (2007) reported that the athletes reached 70% VO_2max and 96% of maximum heart rate, recorded a blood lactate of 16 mmol.L^{-1} and suffered an acute decrement in vertical jump height of 10 cm (17%) after performing these car push/pulls. One criticism of this study would however be that the distance (400 m) and time taken (6-8 minutes) for the car push/pull were substantially more than that seen in strongman training and competition. Nevertheless, the high degree of neuromuscular fatigue produced by the car push/pull would suggest that such strongman exercises (although not necessarily for such large distances and durations) could be useful for the development of muscular hypertrophy, strength, power and endurance (Crewther *et al.*, 2006).

The purpose of this study was to: 1) characterize the temporal aspects of the tyre flip and; 2) compare the fastest and slowest repetitions from each athlete in order to gain additional insight into the temporal determinants of this skill. It was hypothesized that: 1) the second pull/transition phase of the tyre flip would take longer to complete than other phases of the lift;

and 2) that similar to the power clean, variables relating to the second pull and transition phase may differ significantly between the fastest and slowest repetitions, and hence may be an important determinant of performance.

METHOD:

Five male athletes (25 ± 7 years, mass 90 ± 6 kg, height 180 ± 6 cm) gave informed consent to participate in this study. All five had extensive resistance training experience and were very familiar with exercises such as the squat, deadlift, power clean and bench press. Four of the five subjects had also competed in at least one strongman competition in which the tyre flip was an event.

Subjects completed a warm-up which consisted of some sub-maximal sets of deadlifts and power cleans for approximately 10 minutes. This was followed by a few repetitions (2-4) of the tyre flip. The warm-up tyre flips typically took an additional 5-10 minutes as each subject performed them in sets of 1-2 repetitions with moderate rest periods between each repetition and/or set. After completing their warm-up, the subjects were required to perform two sets of six tyre flips with the goal being to perform each repetition as fast as possible. A rest period of three minutes was given between the two sets as is generally recommended for similar forms of training (Havelka, 2004; Crewther *et al.*, 2006). The tyre had a mass of 232 kg, external diameter of 1.50 m and a height when laying on the ground of 0.52 m.

Temporal variables relating to tyre flip performance were recorded by a digital video camera (Sony, PAL, 50Hz, 1/1000 s). The camera was positioned 10 m from the subjects in a plane perpendicular to the intended direction of the tyre flip at a height of ~0.8 m from the ground. All video footage was analyzed using Silicon Coach Pro video analysis software (Dunedin, New Zealand). The temporal measures analyzed in this study were calculated from a number of cumulative times that were obtained using the "stopwatch" function, which records time to 0.02 s. These times were recorded from the frame in which one end of the tyre was first lifted from the ground to when the: 1) tyre first reached 30^o above horizontal; 2) hands were initially taken off the tyre; 3) hands were repositioned on the tyre in readiness for the push; 4) tyre first reached 60^o above horizontal; and 5) tyre was vertical (see Figure 1). For these temporal measures, the "horizontal angle" tool in Silicon Coach was used to determine the frame in which the tyre first reached 30^o, 60^o or 90^o from the horizontal.

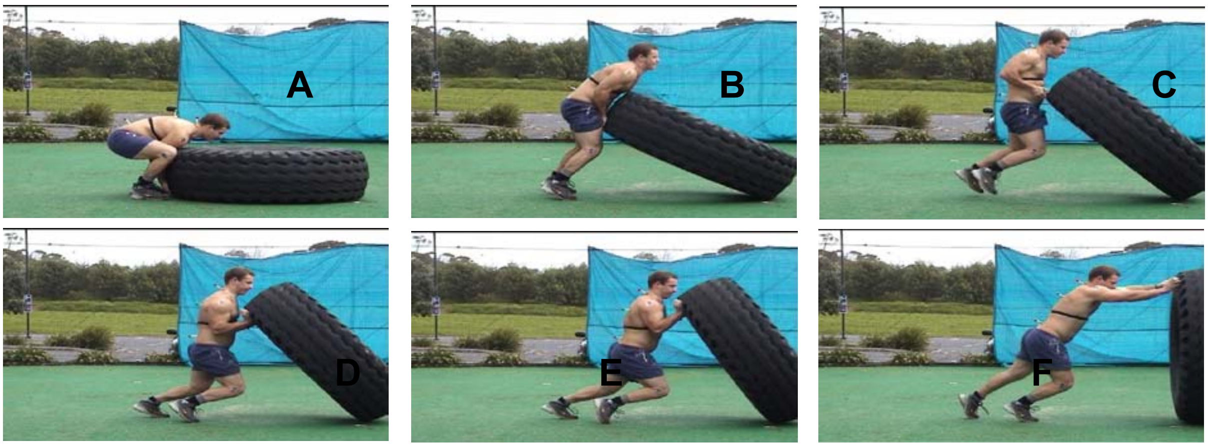

Figure 1: Pictorial representation of the six positions of the tyre flip. A = start, B = tyre 30^o above horizontal, C = hands off, D = hands on, E = tyre 60^o above horizontal, F = tyre vertical.

From each of these cumulative times, the following seven variables were calculated: 1) total time (to vertical); 2) start to 30°; 3) 30° to 60°; 4) 60° to 90°; 5) start to hands off; 6) start to hands on; and 7) hands off to hands on. For all of these variables with the exception of total time, the times were also expressed as a percentage of total lift time.

Means and standard deviations were calculated for all variables for the entire 60 trials as well as the fastest and slowest three trials of each lifter. Two-tailed paired T-tests were used to compare the fastest and slowest repetitions with statistical significance set at $p < 0.05$. All statistical analyses were conducted using Microsoft Excel 2003.

RESULTS:

The absolute and percentage temporal characteristics of selected phases of the tyre flip are presented in Table 1 and 2, respectively. It was apparent that of the three 30° phases from the initiation of the lift until the tyre reached a vertical position, the 30°-60° phase was by far the slowest; accounting for approximately 50% of total time (see Table 1 and 2).

When comparing the fastest and slowest repetitions for each subject, a number of significant differences were observed. For the absolute variables, the fastest repetitions required significantly less time to complete five of the six phases (start to 30°, 30° to 60°, 60° to 90°, start to hands off and start to hands on). When comparing the percentage temporal values, the fastest repetitions took significantly longer to complete the start to 30° and hands off to hands on phases, but required significantly less time for the 30° to 60° phase than the slowest repetitions.

Table 1 Absolute times for selected phases of the tyre flip. Data is presented for all repetitions as well as the fastest and slowest three repetitions per subject.

Phase	All Repetitions (n = 60)	Fastest Repetitions (n = 15)	Slowest Repetitions (n = 15)	P Value
Total time (s)	2.90 ± 1.10	2.25 ± 0.50 **	3.72 ± 1.48	< 0.001
Start to 30° (s)	0.74 ± 0.08	0.71 ± 0.07 *	0.76 ± 0.08	0.022
30° to 60° (s)	1.59 ± 0.93	1.10 ± 0.42 **	2.27 ± 1.33	0.001
60° to 90° (s)	0.57 ± 0.22	0.45 ± 0.08 **	0.68 ± 0.26	0.001
Start to hands off (s)	1.52 ± 0.63	1.26 ± 0.34 **	1.82 ± 0.87	0.004
Start to hands on (s)	1.67 ± 0.64	1.42 ± 0.35 **	1.98 ± 0.88	0.003
Hands off to hands on (s)	0.15 ± 0.05	0.15 ± 0.04	0.17 ± 0.06	0.462

All data is mean ± SD. Total time equals the time from the start of the lift to when the tyre reached a vertical position. *Significant ($p < 0.05$) difference between the fastest and slowest repetitions.
**Significant ($p < 0.01$) difference between the fastest and slowest repetitions.

Table 2 Percentage times for selected phases of the tyre flip. Data is presented for all repetitions as well as the fastest and slowest three repetitions per subject.

Phase	All Repetitions (n = 60)	Fastest Repetitions (n = 15)	Slowest Repetitions (n = 15)	P Value
Start to 30° (%)	28.6 ± 8.8	32.8 ± 6.9 **	24.1 ± 10.2	< 0.001
30° to 60° (%)	51.1 ± 11.1	46.9 ± 8.8 **	56.3 ± 14.3	0.003
60° to 90° (%)	20.3 ± 4.8	20.4 ± 2.8	19.6 ± 7.3	0.667
Start to hands off (%)	54.0 ± 11.9	55.9 ± 7.6	51.8 ± 17.3	0.193
Start to hands on (%)	59.8 ± 12.8	62.8 ± 8.3	56.9 ± 18.0	0.079
Hands off to hands on (%)	5.8 ± 2.4	6.9 ± 2.1 *	5.2 ± 2.5	0.014

All data is mean ± SD. * Significant ($p < 0.05$) difference between the fastest and slowest repetitions.

DISCUSSION:

To the authors' knowledge, this is the first biomechanical study of a strongman event. Consistent with the coaching recommendations of Havelka (2004), it appeared that the athletes generally utilized a four phase movement to complete the tyre flip. This consisted of: 1) an initial pull whereby one end of the tyre was lifted off the ground to just above knee height; 2) a second pull where the athlete attempted to explode the tyre upward and forward from the knee high position; 3) transition where the hands which were supinated come off the

tyre and are repositioned in a pronated position; and 4) the push. Such a four phase movement appears to share some similarities to the four phases of the Olympic lifts e.g. power clean and clean and jerk, although the transition phase of these Olympics lifts typically occurs between the first and second pull (Garhammer, 1984; Souza et al., 2002). Regardless of these similarities, future research needs to be conducted to determine whether the characteristics of a successful Olympic lift are comparable to that of the tyre flip.
Of the three 30^o phases that comprised the 90^o range of motion we analyzed, the 30^o-60^o phase required the greatest time to complete, accounting for ~50% of total time. In addition, this phase also appeared to account for ~80% (1.18 s) of the increase in total time for the slowest vs fastest repetitions (1.46 s). Overall these results suggest that the ability to complete the 30^o-60^o phase as quickly as possible is a primary determinant of tyre flip performance. Visual inspection of the 60 tyre flips also indicated that in many of the slowest trials the tyre's angular velocity approached zero (i.e. a sticking region) when the tyre was 35-45^o above horizontal. This required the athlete to support the mass of the tyre on a flexed leg while repositioning their hands and lowering their centre of mass in readiness for the push, a process that may take valuable seconds. According to our results and the recommendations of Havelka (2004), this technique constitutes poor form as it leads to an increase in tyre flip time and/or reflects athlete fatigue or the use of a tyre that is too heavy.

CONCLUSION:
The results of this study provide the first normative experimental data on the biomechanics of any of the strongman events. As the results suggest that the 30^o-60^o phase takes the longest time to complete and that the largest differences between the fastest and slowest repetitions occurred in this phase, it would appear that this performing this phase quickly is an important aspect of successful tyre flip performance. Strongman competitors should therefore concentrate on improving this phase of the lift in their training. 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 and kinetics as well as electromyography and determine the chronic effect of long-term strongman training on neuromuscular function. Such studies should use high-speed video analysis, as the relatively low temporal resolution of Silicon Coach (0.02 s) may make it difficult to accurately examine the short-duration phases of the tyre flip such as the hands off phase.

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