Interrelationships between strength, anthropometrics, and strongmen performance in novice strongman athletes

Paul W. Winwood  
_Auckland University of Technology_

Justin W. L. Keogh  
_Bond University_, jkeogh@bond.edu.au

Nigel K. Harris  
_Auckland University of Technology_

Follow this and additional works at: _http://epublications.bond.edu.au/hsm_pubs_

Part of the _Sports Sciences Commons_

Recommended Citation  

INTER-RELATIONSHIPS BETWEEN STRENGTH, ANTHROPOMETRICS, AND STRONGMAN PERFORMANCE IN NOVICE STRONGMAN ATHLETES

NOTICE: this is the author’s version of a work that was accepted for publication in . Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published:


Paul W Winwood

Bay of Plenty Polytechnic

Windermere Drive

Tauranga 3143

Ph: 08002677659 x6125

Email: paul.winwood@boppoly.ac.nz
Title: Inter-relationships between strength, anthropometrics, and strongman performance in novice strongman athletes

Running head: Determinants of strongman performance

Authors: Paul W. Winwood.1,2, Justin, W.L. Keogh.1, Nigel, K. Harris.1 & Lisa, M. Weaver.2

1Sport Performance Research Institute New Zealand
School of Sport and Recreation
AUT University, Auckland
New Zealand
2Bay of Plenty Polytechnic
School of Applied Science
Tauranga
New Zealand

Corresponding author:
Paul Winwood
School of Applied Science
Bay of Plenty Polytechnic
Private Bag 12001
Tauranga 3143
08002677659 x6125
Paul.winwood@boppoly.ac.nz
Title: Inter-relationships between strength, anthropometrics, and strongman performance in novice strongman athletes.

ABSTRACT

The sport of strongman is relatively new hence specific research investigating this sport is currently very limited. The purpose of this study was to determine the relationships between anthropometric dimensions and maximal isoinertial strength to strongman performance in novice strongman athletes. Twenty-three semi-professional rugby union players with considerable resistance training and some strongman training experience (22.0 ± 2.4yr, 102.6 ± 10.8kg, 184.6 ± 6.5cm) were assessed for anthropometry (height, body composition, and girth measurements), maximal isoinertial performance (bench press, squat, deadlift and powerclean), and strongman performance (tyre flip, log clean and press, truck pull and farmers walk). The magnitudes of the relationships were determined using Pearson correlation coefficients, and interpreted qualitatively according to Hopkins (14) (90% confidence limits ~ ±0.37). The highest relationship observed was between system force (body mass + squat 1RM) and overall strongman performance (r = 0.87). Clear moderate to very large relationships existed between performance in all strongman events and the squat (r = 0.61 to 0.85), indicating the importance of maximal squat strength for strongman competitors. Flexed arm girth and calf girth were the strongest anthropometric correlates of overall strongman performance (r = 0.79 and 0.70 respectively). The results of this study suggest that body structure and common gym based exercise strength are meaningfully related to strongman performance in novice strongman athletes. Future research should investigate these relationships using more experienced strongman athletes and determine the relationships between changes in anthropometry, isoinertial strength and strongman performance in order to determine the role of anthropometry and isoinertial strength in the sport of strongman.

Key Words relationships, isoinertial, squat, body mass, body structure
INTRODUCTION

The sport of strongman is relatively new and little information exists in the scientific literature as to the determinants of successful strongman performance. It is well known that maximal strength is a major factor in determining performance across a variety of sports (37), especially in sports such as weightlifting and powerlifting. However, what is not well known regarding strongman is what types of strength are most related to performance and how this might be influenced by a variety of anthropometric characteristics. Understanding how strength and anthropometry relate to performance of a specific event or sport is a key issue in maximizing the transfer of training to performance and therefore improving training efficiency (34).

Various strength and anthropometric variables have been tested in sports to evaluate the effects of training (26), to select athletes (24), to distinguish among different competition levels (19) and to predict performance (43). The rationale behind this approach is that the aforementioned variables are important for movement performance. However, the correlation studies that have investigated standard strength tests (for example, 1RM, maximum isometric voluntary force and rate of force development), anthropometrics, and movement performance have provided both strong (19, 34, 40, 43) and weak correlations (23, 38) to performance. Thus, the specific relationship among these variables may vary from sport to sport and across different development levels of athletes i.e. elite to novice.

Of the studies so far that have investigated the sport of strongman, the main emphasis has been on the metabolic and biomechanical (kinematic determinants of performance and lower back/hip loads) demands of these exercises (4, 20, 21, 32). Recently, the imprecise nature of the overload in strongman training when dealing with large groups of athletes has also gained attention (1). Baker (1) attempted to develop a mixed training session of strongman exercises such as tire flipping, log carrying and water filled conduit carrying coupled with some running conditioning for elite rugby league athletes. The
training session was designed to elicit mean player heart rates of 165-175 beats per minute (bpm), in order to replicate the average heart rate (HR) conditions in a game. However due to the different bodyweights and strength levels of the athletes, two of the strongest players had a mean HR less than 165 bpm. This result suggests that higher levels of maximal strength and perhaps body mass may be advantageous in the sport of strongman. To date, however, no quantifiable evidence has been advanced to support this speculation.

Strongman events typically last from a few seconds to one minute and incorporate functional movements in multiple planes that challenge the whole musculoskeletal system in terms of both strength and physiological demands (32). Hence the sport of strongman is multifactorial in nature with a range of muscular capabilities such as maximal muscular strength, power, anaerobic endurance, grip strength and core stability believed to be needed to perform successfully in the various strongman events (11). To date no research has examined the relationships between maximal strength (as assessed in a gym-based environment) and anthropometrics to strongman event and competition performance. Such research would be beneficial to strongman athletes and those wishing to participate in the sport of strongman to determine the degree to which structural dimensions and strength performance influence strongman performance. The purpose of this study was to develop our understanding as to what variables are the most important for success in novice strongman performance and help guide programming for individuals wishing to commence this sport.

Within the present study it was hypothesized that strong relationships would exist between gym based strength tests and standard anthropometric measures to strongman competition performance in novice strongmen. If such results are found, it would support traditional gym based training and the transferability of traditional training methods to strength and power sports such as strongman.
METHODS

Experimental Approach to the problem

A cross sectional experimental study was designed by the authors to examine the relationship between maximal strength and anthropometrics to strongman competition performance in novice strongmen. Subjects competed in a strongman competition, and ten days later performed anthropometric and 1RM testing. The relationship between these variables was assessed by Pearson’s product moment correlations. Our hypothesis was that, strong relationships would exist between gym based strength tests and standard anthropometric measures to strongman competition performance in novice strongmen, as higher levels of strength and body mass may be advantageous in the sport of strongman.

Subjects

Twenty-three male semi-professional rugby players volunteered to participate in this study. All subjects regularly performed 1RM testing as part of their fitness testing and had an extensive strength training background; including experience with the bench press, squat, deadlift, power clean and strongman exercises. The subjects were performing regular strength training as part of their pre-season training phase. The strongman competition organized for this study was either the first or second such competition that these athletes had competed. The subjects’ mean (±SD) age, body mass, and heights were 22.0 ± 2.4 years, 102.6 ± 10.8kg, and 184.6 ± 6.5cm respectively. All subjects provided written informed consent after having being briefed on the potential risks associated with this research. This study was approved by the AUT University Ethics Committee, Auckland, New Zealand.

Strongman testing

Four strongman events were performed in a competition: the tire flip; farmer’s walk; log clean and press; and truck pull. These events were chosen for this study as they: 1) are all common strongman events that assess varying types of strongman “strength”; 2) have all been considered appropriate conditioning exercises for a variety of athletes (1, 12); and 3) were incorporated into the subjects pre-
season training so that the subjects were familiar with these exercises. Strongman overall competition performance was calculated by adding each subjects placing in each of the four events together. For example a participant who placed 1\textsuperscript{st}, 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} across the four events gained a total score of $1 + 2 + 3 + 4 = 10$ points. The subjects with the lowest total and highest total score in the competition were first and last place, respectively.

After a \~10-minute standardized low intensity warm-up (i.e. aerobic training zone based on approximately 60 to 70\% max HR) which consisted of dynamic stretching, and light jogging interspersed with bodyweight exercises, all subjects completed the four strongman exercises in a randomized order to prevent order effects, separated by a rest period of \~10-minutes. Specifics of each exercise are detailed below.

\textit{Tire flip}

The tire (Doublecoin REM2 23.5R25 - mass of 280kg, diameter of 163cm and section width of 70cm) was positioned on the ground in front of the subjects. The subjects were instructed to flip the tire end-over-end as many times as they could in 40-seconds, using a technique similar to previously described (21). A completed repetition was recognized when the tire performed a full flip. The timing started on the referee’s signal with the participant in their starting position with their hands on the tire that was laid flat on the ground. The total number of tire flips in 40-seconds was the outcome measure.

\textit{Farmer’s walk}

The customized farmers walk bars with a length of 1300mm and handle thickness of 32mm diameter, were each loaded with two 20kg Eleiko training discs (Elieko Sport, Sweden) to give a total mass of 58kg per bar. The farmers bars were positioned on the ground on each side of the subjects who were instructed to pick up the bars in each hand and asked to complete as many 25m laps as possible with a 180° degree turn at the end of each 25 m, over a 40-second period. The subjects were allowed as many
drops of the bars as they needed, although they were challenged to complete the greatest distance (measured to the nearest 0.5m) that they could in 40-seconds, which was the outcome measure. Final measurement was taken at the front foot at the end of the 40-second period. The timing commenced with the first breaking of the farmers bars off the ground.

**Log clean and press**

The customized strongman metal log (diameter 20cm) loaded with two 10kg Eleiko Eleiko training discs (Elieko Sport, Sweden) to a total mass of 75kg was positioned on the ground in front of the subjects. Subjects were instructed to bend their knees, lean forward and grasp the handles inside the metal log in a hammer (neutral) grip. The subjects were instructed to lift the log from the ground to above their heads, as many times as possible in 60-seconds, which was the outcome measure. Subjects could chose any technique they wished providing that, for a repetition to be counted, it had to start from the floor and required the subjects to be standing upright with feet together, with knees and elbows extended overhead. Once this position was obtained, the referee announced “good lift”, and the subjects could then lower the log for the next repetition.

**Truck pull**

The subjects were strapped in front of a Toyota Hilux truck (mass of 2.5 tons) via a customized harness that crossed the waist and shoulders of the participant. The subjects started the truck pull on a slight uphill grade of 1-2° (performed on an asphalt surface) in a four-point power position and tried to accelerate the truck forward as quickly as possible using powerful triple extension of the lower body. The subjects could use their arms to pull on the ground and to provide some stability if required. The distance that the truck was pulled (to the nearest 0.5m) in 40-seconds was the outcome measure.
Anthropometric Assessment

For the purposes of this study, anthropometry was sub-divided into three categories; height, body composition (body mass, fat free mass (FFM), muscle mass (MM), percentage of body fat (%BF)) and girth measurements. All anthropometric assessments i.e. height (stature) and segment girths, were assessed by one of the researchers who was a qualified (Level III) International Society for the Advancement of Kinanthropometry anthropometrist. The protocols used were those previously described by Norton & Olds (33). Stature was measured using a portable stadiometer (Seca 214). Segment girths (chest, upper arm (flexed), gluteal, thigh and calf) were measured using a Lufkin tape measure. Body composition was measured using a bioelectrical impedance machine (InBody230, Biospace). Recent research indicates that the InBody230 is a valid measure of body composition as high correlations (r > 0.85) existed between the Inbody230 and DEXA for the range of body composition variables used in the present study (42). All girths were measured in duplicate, with a technical error of measurement (TEM) of < 1% required. If the TEM > 1% for any variable, then a third measure was taken. The averages of the two (closest) measures were used for data analysis.

Maximal Strength

The maximal strength assessments were the squat, bench press, deadlift, and power clean one repetition maximum (1RM). The warm up, loading increments and rest periods used were according to previously established protocols (41). Maximal strength testing was carried out over a two-day period. The bench press was performed on day one and the squat, power clean, and deadlift were performed on day two. Maximum strength was assessed by a 1RM performed with a free-weight Olympic-style barbell. Bench press and squat 1RM were assessed using the methods outlined by Baker (2). Completed lifts in the deadlift and power clean were recognized when the subjects were standing fully upright with the applied load.
For the purpose of this study, each subject's squat 1RM and body mass were added to create the variable ‘system force’. This variable was created as the results of Baker (1) and Keogh et al. (20) suggest that ‘system force’ could be highly related to strongman performance, especially in the truck pull.

**Statistical Analysis**

Means and standard deviations were used as measures of centrality and spread of data. The relationship between 1RM, and anthropometrics, to strongman competition performance were analyzed using Pearson correlation coefficients, which based on the sample size of 23 had uncertainty (90% confidence limits) of ~±0.37 (14). The magnitudes of correlations were described as trivial (0.0-0.1), low (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9), or nearly perfect (0.9-1.0) (13).

Inferences about the true (large-sample) value of the correlations were based on uncertainty in their magnitude (3); if the 90% confidence interval (derived for correlations via the Fisher z transformation) (8) overlapped small positive and negative values (i.e. ±0.1), the magnitude was deemed unclear; otherwise the magnitude was deemed to be the observed magnitude. For trivial correlations the upper confidence limits were ~±0.37. Thus the power of this study was such that only correlations >0.28 and <-0.28 were considered clear. Correlations were analyzed using the Statistical Package for the Social Sciences (Version 16.0, SPSS for Windows), and 90% confidence intervals were calculated using a statistical spreadsheet designed by Hopkins (14).

**RESULTS**

The descriptive statistics of all measured outcome and predictor variables may be observed in Table 1.
The results for the interrelationships among strength and anthropometric variables detailed in Table 2 showed a spread of trivial to very large correlations. Clear large to nearly perfect correlations existed between the system force measure (body mass + 1RM squat) and all 1RM strength measures ($r = 0.57–0.96$). The interrelationships between body composition (body mass, FFM and MM) and strength measures typically showed clear moderate to large correlations for all variables ($r = 0.47–0.59$) except the deadlift ($r = 0.24–0.29$).

Low and trivial correlations were observed for height and strength measures ($r = -0.09–0.12$), and height and girth measures ($r = 0.10–0.27$) except for gluteal girth where a clear moderate correlation existed ($r = 0.43$). The interrelationships of height to body mass, FFM and MM show clear moderate to large correlations ($r = 0.49–0.73$).

The interrelationship among girth and strength measures show trivial to very large clear correlations ($r = 0.02–0.82$). Clear moderate to very large correlations existed between flexed arm girth, chest girth, mid thigh girth, calf girth and the bench press and squat ($r = 0.45–0.82$).

The results for the interrelationships among strongman performance and strength measures, body composition, height and girth measures detailed in Table 3 show a range of trivial to very large clear correlations ($r = 0.03–0.87$).

Clear moderate to very large correlations existed between overall strongman competition performance and 1RM strength measures ($r = 0.45–0.85$). Clear moderate to very large correlations existed among 1RM strength measures and strongman event performance ($r = 0.44–0.82$), except for the deadlift where unclear and clear low correlations existed with truck pull ($r = 0.17$) and tire flip performance ($r$...
Determinants of Strongman Performance

The system force measure (body mass + 1RM squat) demonstrated clear large to very large correlations with all strongman event performance ($r = 0.64 - 0.87$) and was the highest reported correlation ($r = 0.87$) with overall strongman competition performance in this study.

The interrelationship between body composition variables (body mass, FFM, MM and body fat %), and all aspects of strongman performance show trivial to large clear correlations ($r = 0.05 - 0.73$). Clear moderate to large correlations existed for body mass, FFM and MM to all aspects of strongman performance ($r = 0.43 - 0.73$). Unclear trivial correlations existed between body fat percentage and all aspects of strongman performance ($r = 0.05 - 0.13$) except for the truck pull where a clear moderate correlation was observed ($r = 0.38$).

Unclear low and trivial interrelationships existed for height and all aspects of strongman performance ($r = -0.15$ to $0.03$). The relationships among the girth measures and all aspects of strongman performance typically showed clear moderate to very large correlations ($r = 0.33 - 0.79$). Exceptions were for gluteal girth and log clean and press ($r = 0.27$), chest girth and farmers walk ($r = 0.28$) and calf girth and farmers walk performance ($r = 0.19$) which all showed unclear low correlations.

The interrelationship between strongman competition performance and strongman event performance detailed in Table 4 show clear large to very large correlations ($r = 0.69 - 0.88$). Clear moderate to very large correlations were observed between individual strongman events ($r = 0.31 - 0.81$). The tire flip and farmers walk had the strongest and weakest interrelationships (respectively) with overall strongman competition performance.
DISCUSSION

The aim of the present study was to examine the interrelationships between 1RM strength measures and anthropometric variables to strongman competition performance in novice strongman competitors. It was hypothesized that strong relationships would exist among many of these variables.

The results of this study provide the first data on the interrelationships between 1RM strength measures and anthropometric variables to strongman competition performance. As hypothesized, strong relationships were observed between many 1RM strength and anthropometric measures to strongman competition performance, with the highest correlate of overall strongman competition performance being system force (body mass + 1RM squat) (r = 0.87). This result suggests that being heavy and strong in the squat is advantageous for successful strongman performance.

The results of the present study demonstrated that the tire flip and the farmers walk had the strongest and weakest interrelationships with overall strongman competition performance (r = 0.88 and 0.69), respectively. The farmers walk may have assessed different strength qualities (e.g. foot speed and grip strength) instead of maximal strength compared to the other strongman events (11). This was reflected in the clear large correlation between the deadlift and farmers walk (r=0.55) where it’s generally thought that grip strength can be a primary determinant of deadlift performance.

The strongest correlation that existed between the farmers walk and the other strongman events was the truck pull, where a clear moderate correlation was shown (r = 0.47). This may be due to some similarities in the movements associated with these exercises. The farmers walk and truck pull both involve horizontal motion of the total body with the feet in a split position, compared to the log clean and press and tire flip which are predominantly performed with two feet side by side in a vertical plane. Differences also exist between these events in the types of strength required. The log clean and
press and tire flip involve upper body pushing strength which is not seen in the farmers walk and truck pull events.

Of the 1RM strength measures the squat and bench press demonstrated the highest interrelationships with overall strongman competition performance ($r = 0.85$ and $0.78$), respectively. The results demonstrate that the squat had the strongest relationship to all the strongman events except the log clean and press ($r = 0.71$), where the bench press showed a slightly stronger relationship ($r = 0.76$). This finding may due to the specificity of the pressing action in the log press and the transferability of the bench press strength in performing this action. Previous research has shown significant relationships between bench press strength and grinding performance in Americas Cup sailors (34). Significant relationships have also been reported between squat strength and sprinting ability (31). Schoenfeld (35) suggested that the squat has biomechanical and neuromuscular similarities to a wide range of functional movements. The results from the current study support the use of the bench press and squat as fundamental gym based exercises for novice strongman competitors.

The clear large correlation between the power clean and the log clean and press ($r = 0.67$) could be explained by the similarities associated with these exercises (i.e. main agonists, specific joint angles and direction of force application, muscle sequence patterns, specific postures, and velocities of movement). Stone and colleagues (36) have suggested that the more similar a training exercise is to actual physical performance, the greater the probabilities of transfer.

Low to clear large correlations existed between the deadlift and all aspects of strongman performance ($r = 0.17$-$0.55$). The deadlift demonstrated low interrelationships to the truck pull and tire flip ($r = 0.17$ and $0.29$ respectively). The low relationship associated with the truck pull and deadlift may be due to the lack of biomechanical specificity associated with these exercises. The clear low correlation between the deadlift and tire flip is however more surprising, as the start of the tire flip appears similar
to the posture employed at the beginning of a deadlift. Subjects were however, tested with the conventional deadlift and the tire flip starts in a semi-sumo deadlift position. Biomechanical differences exist between sumo and conventional deadlifts, with significant differences in ankle and knee moments and moment arms (7). The sumo deadlift has higher quadriceps involvement compared to the conventional deadlift (7), which may help explain the very large clear correlation between the squat and tire flip ($r = 0.82$).

Recent research has also demonstrated that the duration of the second pull (i.e. the phase where the tire moved from just above the knee to the hands-off position prior to the push) and not the first pull (i.e. the phase where the tire first comes off the ground to it vertically rising to just above knee height) was the primary difference between slow and fast flips, further diminishing the expected relationship between deadlift strength and tire flip performance (21). Interestingly, the present study also found unclear low correlations between the deadlift and the anthropometric variables (height, FFM, body mass, chest girth and mid-thigh girth) which are in contrast to the moderate correlations previously reported (15, 29, 30).

Clear moderate and large correlations were demonstrated between body mass and all aspects of strongman performance. The range of correlations between body mass and strongman performance in this study ($r = 0.45-0.73$) are comparable to the correlations between body mass and 1RM strength performance previously reported (10, 15, 27-30). These results suggest that in trained athletes a larger body mass is beneficial for strength performance, reflecting greater FFM and larger muscle cross sectional area. Previous research has established that the force a muscle can exert is related to its cross sectional area (22), which is more beneficial for muscle force production (5, 18).

The correlations between FFM and all aspects of strongman performance were clear and moderate, however the log clean and press had the weakest relationship of the four strongman exercises to FFM.
Determinants of Strongman Performance

This result may be due to the complexity of the log clean and press movement. This type of movement which is similar to the clean and jerk in Olympic lifting incorporates a vast array of musculature and a wide range of abilities. Athletes would appear to not only need strength, but also balance, coordination, flexibility and speed when performing this movement. Prior research has shown that the relationships between anthropometric variables and strength performance decrease with exercise complexity (15, 29). Another contributing factor that may explain the weaker relationship between FFM and the log clean and press in this study was that the log clean and press went for 60-seconds rather than the 40-seconds used for the other strongman events. Hence, the 60-second log clean and press event may have measured somewhat different strength qualities i.e. muscular and anaerobic endurance than the other strongman exercises. While we acknowledge this limitation, the log clean and press is commonly performed for 60 – 90-seconds in competition. In addition, it was important when running correlations that all subjects were able to obtain a non-zero score for each of the four events. We felt that if the log clean and press was limited to 40-seconds, a heavier weight would have been needed to get a spread of performance between these athletes. The smaller, weaker athletes might then have got no repetitions, which would then have reduced the sample size and increased the uncertainty confidence limits for all correlations involving the log clean and press.

As with all strongman competitions, all competitors in the present study performed the strongman events with the same loads. While we acknowledge that the larger and stronger individuals were at an advantage, the purpose of the present study was to test the hypothesis that strong relationships would exist among the dependent and independent variables represented in this study. In addition, our competition followed standard strongman competition rules as the score in each event was determined by placement. However, in our scoring system the subjects’ with the lowest total and highest total score in the competition were first and last place, respectively. This is in contrast to the scoring method seen in the World’s Strongest Man (WSM) where the highest score is the winner and lowest score is last place. However, both scoring systems would have determined a similar outcome.
The correlations between FFM and strongman event and overall performance ($r = 0.43$-$0.63$) in the present study are comparable to correlations reported between FFM and 1RM strength performance in college football players (29, 30) and predominantly national-level powerlifters (15). However, the correlations from the present study are much lower than that reported ($r = 0.86$-$0.94$) in elite powerlifters (5). Deliberate practice, technique and neurological adaptations (i.e. motor unit firing rate and motor unit synchronization) may explain the higher correlations reported for elite than sub-elite powerlifters. It would be interesting if the greater correlations found between FFM and performance for elite than sub-elite powerlifters would also apply to elite compared to novice strongman competitors.

The clear moderate and very large correlations that existed between height, and FFM, and MM, and body mass ($r = 0.73$, $0.72$ and $0.49$ respectively), supports the concept that taller individuals are heavier and have greater FFM and therefore greater potential to lift heavier loads. However, powerlifters and Olympic weightlifters whose sports involve the lifting of very heavy loads are generally average to below average in height and have relatively short limbs (16, 25, 28, 39). These anthropometric characteristics would be advantageous in these weight-lifting sports as the work and torque required to lift a load are proportional to the length of the lever (body segment) (16, 17). Taller individuals with longer levers require more muscular work and torque to lift a given load which may be disadvantageous for strength exercises such as the squat and pressing events. In the sport of strongman being taller may be advantageous in some events such as the atlas stones (when loading on to high platforms), vertical keg toss and carrying events such as the farmers walk due to the relationship between height, step length and running speed. Interestingly, in the present study very low and trivial relationships existed between height and all measures of 1RM and strongman performance. Such a result suggests that height and limb segments may not be determining factors in novice strongman competitions, at least those involving the tire flip, farmer’s walk, log clean and press, and the truck pull. This result does raise some interesting questions for these events. Although this study
did not measure limb lengths, which may be a limitation to this study, they are however related to overall stature (within certain limits) (6). It could be argued that longer arms and a longer torso would allow for greater leverage while flipping a tire; however it could also be argued that shorter arms would be more beneficial for the pressing of the tire. An interesting area for future research could be to determine the kinetic and kinematic differences in strongman events technique among strongmen of different heights and limb lengths.

The results of the present study demonstrate that body fat percentage was only trivially related to all aspects of strongman performance except the truck pull where a clear moderate correlation was observed (r = 0.38). This relationship suggests that higher levels of body fat may be somewhat beneficial in the truck pull where higher levels of body mass could assist in developing greater momentum to overcome the inertia of the truck at the start of the pull.

Of the girth measures, flexed arm girth and calf girth demonstrated the highest interrelationships with strongman competition performance (r = 0.79 and 0.70), respectively. This was also the case for the relationship between girths and 1RM strength, whereby the flexed arm girth and calf girth had the greatest relationship to all strength scores except for squat, whereby the calf girth correlation (r = 0.52) was slightly less than mid-thigh girth (r = 0.53).

The relationship between flexed arm girth and squat (r = 0.72) was very similar to what had been previously reported for powerlifters (15), however the relationship between max flexed arm girth and the bench press was slightly higher in the present study (r = 0.82) compared to Keogh and colleagues (R = 0.71) (15). Individuals with larger arms performed better in the bench press exercise, and in overall strongman competition performance. However, the current study indicated that resistance trained athletes with greater thigh size did not always have greater lifting ability in the squat. This finding was similar to that found by Mayhew and colleagues (29). Interestingly, individuals with larger
thigh size performed better in the truck pull. The differences between these strength exercises and the magnitude of the relationship with thigh girth may be due to the different muscle contribution and postures employed in the squat and truck pull. The posture employed in the truck pull may place more emphasis on the quadriceps whereas in a wider stance back squat a larger relative contribution might come from the hamstrings, gluteus group and erector spinal muscles. The higher association between thigh girth and truck pull rather than squat performance may also reflect the very strong positive relationship between thigh girth and body mass ($r = 0.89$), whereby greater body masses assist in the truck pull as long as the athlete is leaning forwards throughout the pull.

An unclear low correlation between calf girth and farmers walk ($r = 0.19$) was observed in the present study. This is surprising as it is known that the plantarflexors contributes to the gait cycle (mid-stance and terminal stance) through control of ankle dorsiflexion and plantarflexion (9). A greater calf girth would be thought to allow for more force to be produced during plantarflexion which would be beneficial in the gait cycle under heavy loading. The results of the present study may indicate that muscle contribution and gait kinematics during the normal gait cycle may change considerably in an event such as the farmers walk. However, further research is needed to validate such a view.

There were a number of limitations within the present study. We assessed strongman performance in only four events with semi-professional rugby union players. Further research is therefore required to confirm if similar results would be found in competitions involving more or other types of strongman events and for a different sample group, such as elite strongman competitors. It was also observed that loading limitations may have existed in the farmers walk. However, the handles (which had been used in training by all subjects) were larger in diameter than regulation barbell size and were quite smooth, thereby increasing the grip demands over what would be expected in many other farmers bars. It should also be noted that correlations can only give insights into associations and not into cause and
effect; therefore longitudinal studies are needed to provide valid information in regard to how changes in body composition and/or maximal strength affect strongman performance.

In conclusion, this study investigated relationships between anthropometric variables and 1RM strength measures to strongman competition performance in novice strongman athletes. The highest interrelationship with strongman competition performance was system force (body mass + 1RM squat). The results of this study indicate that maximum strength and anthropometric variables and play a significant role in the determination of strongman performance in novice strongman athletes.

**PRACTICAL APPLICATIONS**

Understanding the relationships that exist between maximal strength, anthropometrics and strongman performance can assist in the identification of the determinants of strongman performance, hence providing a theoretical underpinning for training practice in this sport. The data represented in this study demonstrates the strength and anthropometric requirements to compete successfully in a novice strongman competition. The data supports traditional based training and the transferability of traditional training methods to the sport of strongman. This data can be used by strength and conditioning coaches and novice strongman competitors to help guide programming, which can be used to maximize the transfer of training to strongman performance and therefore improve training efficiency.
REFERENCES


Acknowledgments

The authors would like to thank the subjects of North Harbour rugby club for their participation and assistance with this research.

Legend Tables

Table 1: Descriptive statistics (mean ± standard deviation), for strongman events, strength, and anthropometric measures................................................................. 24
Table 2: Intercorrelation matrix for maximal strength and anthropometrics variables ............................................. 26
Table 3: Intercorrelation matrix between strength, anthropometrics and strongman events and overall competition performance......................................................................................................................... 28
Table 4: Intercorrelation matrix between strongman events and overall competition performance ............ 30
Table 1: Descriptive statistics (mean ± standard deviation), for strongman events, strength, and anthropometric measures.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>184.5</td>
<td>± 6.5</td>
</tr>
</tbody>
</table>

*Strongman Performance Measures*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire flip (reps)</td>
<td>6.6</td>
<td>± 2.3</td>
</tr>
<tr>
<td>Log clean and press (reps)</td>
<td>7.6</td>
<td>± 3.2</td>
</tr>
<tr>
<td>Truck pull (m)</td>
<td>18.8</td>
<td>± 8.5</td>
</tr>
<tr>
<td>Farmers walk (m)</td>
<td>64.0</td>
<td>± 9.9</td>
</tr>
</tbody>
</table>

*Strength measures*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press (kg)</td>
<td>132.2</td>
<td>± 16.6</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>167.1</td>
<td>± 22.8</td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>189.4</td>
<td>± 17.7</td>
</tr>
<tr>
<td>Powerclean (kg)</td>
<td>105.6</td>
<td>± 10.3</td>
</tr>
</tbody>
</table>

*System Force measure*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass + 1RM squat (kg)</td>
<td>269.6</td>
<td>± 29.4</td>
</tr>
</tbody>
</table>

*Body Composition*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass (kg)</td>
<td>102.2</td>
<td>± 10.8</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>88.1</td>
<td>± 8.6</td>
</tr>
<tr>
<td>MM (kg)</td>
<td>51.4</td>
<td>± 5.2</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>13.6</td>
<td>± 4.7</td>
</tr>
</tbody>
</table>

*Girth Measures*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>±  SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexed arm girth (cm)</td>
<td>41.1</td>
<td>± 2.7</td>
</tr>
<tr>
<td>Body Measurement</td>
<td>Value</td>
<td>±</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------</td>
<td>----</td>
</tr>
<tr>
<td>Chest girth (cm)</td>
<td>111.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Gluteal girth (cm)</td>
<td>107.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Mid thigh girth (cm)</td>
<td>61.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Calf girth (cm)</td>
<td>42.0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

**Key:** FFM = Fat Free Mass, MM = Muscle Mass
## Table 2: Intercorrelation matrix for maximal strength and anthropometrics variables

<table>
<thead>
<tr>
<th></th>
<th>Bench Press</th>
<th>Squat (kg)</th>
<th>Deadlift (kg)</th>
<th>Power-clean</th>
<th>System Force</th>
<th>Body mass</th>
<th>FFM (kg)</th>
<th>MM (kg)</th>
<th>Body fat (%)</th>
<th>Height (cm)</th>
<th>Flexed arm girth (cm)</th>
<th>Chest girth (cm)</th>
<th>Gluteal girth (cm)</th>
<th>Mid thigh girth</th>
<th>Calf girth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>0.69*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>0.42†</td>
<td>0.56*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power-clean (kg)</td>
<td>0.47†</td>
<td>0.62*</td>
<td>0.37†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Force (kg)</td>
<td>0.70**</td>
<td>0.96**</td>
<td>0.57*</td>
<td>0.65*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>0.47†</td>
<td>0.54*</td>
<td>0.24</td>
<td>0.26</td>
<td>0.74**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>0.57*</td>
<td>0.53*</td>
<td>0.28</td>
<td>0.48†</td>
<td>0.69*</td>
<td>0.85**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MM (kg)</td>
<td>0.59*</td>
<td>0.55*</td>
<td>0.29^</td>
<td>0.50*</td>
<td>0.71**</td>
<td>0.84**</td>
<td>1.00*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>-0.08</td>
<td>0.02</td>
<td>-0.01</td>
<td>-0.32†</td>
<td>0.03</td>
<td>0.39†</td>
<td>-0.15</td>
<td>-0.17</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.12</td>
<td>-0.09</td>
<td>-0.09</td>
<td>0.10</td>
<td>0.04</td>
<td>0.49†</td>
<td>0.73**</td>
<td>0.72**</td>
<td>-0.37†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexed arm girth (cm)</td>
<td>0.82**</td>
<td>0.72*</td>
<td>0.49†</td>
<td>0.39†</td>
<td>0.80**</td>
<td>0.70**</td>
<td>0.65*</td>
<td>0.27</td>
<td>0.10</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest girth (cm)</td>
<td>0.45†</td>
<td>0.50*</td>
<td>0.14</td>
<td>0.06</td>
<td>0.64*</td>
<td>0.83**</td>
<td>0.57*</td>
<td>0.57*</td>
<td>0.63*</td>
<td>0.15</td>
<td>0.60*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluteal girth (cm)</td>
<td>0.22</td>
<td>0.20</td>
<td>0.17</td>
<td>0.02</td>
<td>0.41†</td>
<td>0.88**</td>
<td>0.70**</td>
<td>0.69*</td>
<td>0.51*</td>
<td>0.43†</td>
<td>0.39†</td>
<td>0.74**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Clear, very large correlation. *Clear, large correlation. † Clear, moderate correlation. ^ Clear, low correlation.**

FFM = Fat Free Mass, MM = Muscle Mass, System Force = Body mass + 1RM squat

<table>
<thead>
<tr>
<th></th>
<th>0.51*</th>
<th>0.53*</th>
<th>0.12</th>
<th>0.22</th>
<th>0.41†</th>
<th>0.89**</th>
<th>0.70**</th>
<th>0.70**</th>
<th>0.51*</th>
<th>0.27</th>
<th>0.76**</th>
<th>0.89**</th>
<th>0.69*</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid thigh girth (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf girth (cm)</td>
<td>0.67*</td>
<td>0.52*</td>
<td>0.25</td>
<td>0.39†</td>
<td>0.64*</td>
<td>0.78**</td>
<td>0.64*</td>
<td>0.65*</td>
<td>0.42†</td>
<td>0.12</td>
<td>0.79**</td>
<td>0.74**</td>
<td>0.57*</td>
<td>0.77**</td>
</tr>
</tbody>
</table>
Table 3: Intercorrelation matrix between strength, anthropometrics and strongman events and overall competition performance

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Log clean &amp; Press (reps)</th>
<th>Truck pull (m)</th>
<th>Farmers Walk (m)</th>
<th>Tire Flip (reps)</th>
<th>Strongman competition performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>-0.15, ±0.36</td>
<td>0.12, ±0.36</td>
<td>0.14, ±0.36</td>
<td>0.03, ±0.37</td>
<td>0.05, ±0.37</td>
</tr>
</tbody>
</table>

**Strength performance measures**

- Bench Press (kg) 0.76, ±0.16** 0.56, ±0.25* 0.46, ±0.29† 0.70, ±0.19** 0.78, ±0.15**
- Squat (kg) 0.71, ±0.21** 0.61, ±0.26* 0.64, ±0.25* 0.82, ±0.15** 0.85, ±0.12**
- Deadlift (kg) 0.48, ±0.31† 0.17, ±0.37 0.55, ±0.28* 0.29, ±0.35^ 0.45, ±0.31†
- Powerclean (kg) 0.67, ±0.23* 0.44, ±0.32† 0.45, ±0.31† 0.48, ±0.31† 0.60, ±0.26*

**System Force measure**

- Body mass + 1RM squat 0.71, ±0.22** 0.68, ±0.47* 0.64, ±0.26* 0.81, ±0.15** 0.87, ±0.11**

**Body Composition**

- Body mass (kg) 0.45, ±0.30† 0.73, ±0.19** 0.47, ±0.30† 0.51, ±0.29* 0.66, ±0.23*
- FFM (kg) 0.43, ±0.31† 0.57, ±0.27* 0.48, ±0.30† 0.53, ±0.28* 0.63, ±0.24*
- MM (kg) 0.44, ±0.31† 0.57, ±0.27* 0.49, ±0.29† 0.55, ±0.27* 0.64, ±0.24*
**Determinants of Strongman Performance**

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>± 90% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body fat (%)</td>
<td>0.13, ±0.36</td>
<td>0.38, ±0.32↑</td>
</tr>
</tbody>
</table>

**Girth Measures**

<table>
<thead>
<tr>
<th>Measure</th>
<th>r</th>
<th>± 90% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexed arm girth (cm)</td>
<td>0.68, ±0.22*</td>
<td>0.74, ±0.19**</td>
</tr>
<tr>
<td>Chest girth (cm)</td>
<td>0.54, ±0.28*</td>
<td>0.66, ±0.23*</td>
</tr>
<tr>
<td>Gluteal girth (cm)</td>
<td>0.27, ±0.36</td>
<td>0.54, ±0.28*</td>
</tr>
<tr>
<td>Mid thigh girth (cm)</td>
<td>0.50, ±0.30*</td>
<td>0.70, ±0.21**</td>
</tr>
<tr>
<td>Calf girth (cm)</td>
<td>0.75, ±0.18**</td>
<td>0.68, ±0.22*</td>
</tr>
</tbody>
</table>

Data expressed as: r, ±90% CI

**Clear, very large correlation. *Clear, large correlation. † Clear, moderate correlation. ^ Clear, low correlation.**

FFM = Fat Free Mass, MM = Muscle Mass
Table 4: Intercorrelation matrix between strongman events and overall competition performance

<table>
<thead>
<tr>
<th></th>
<th>Tire flip (reps)</th>
<th>Log clean and press (reps)</th>
<th>Truck pull (m)</th>
<th>Farmers walk (m)</th>
<th>Strongman competition performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire flip (reps)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log clean and press (reps)</td>
<td>0.81**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck pull (m)</td>
<td>0.64*</td>
<td>0.59*</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmers walk (m)</td>
<td>0.45†</td>
<td>0.31†</td>
<td>0.47†</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Strongman competition performance</td>
<td>0.88**</td>
<td>0.82**</td>
<td>0.82**</td>
<td>0.69**</td>
<td>1.00</td>
</tr>
</tbody>
</table>

** Clear, very large correlation. *Clear, large correlation. † Clear, moderate correlation.