MEASUREMENT OF PEAK FORCE EXPERIENCED BY MALES DURING ASSISTED AND UNASSISTED PULL-UPS

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The purpose of this study was to measure the peak force (PF) generated by males while performing assisted pull-ups (APU) and unassisted pull-ups (UPU) with pronated (PUP) and supinated (SUP) hand grips. Twenty-five men (mean ± SD: age= 23 ± 3 y; height= 180 ± 6 cm; weight= 88 ± 14 kg, APU: N=12, UPU: N=13) participated. Participants performed 2 sets of 10 pull-ups (PU) (1 PUP, 1 SUP) in randomized order on a PU bar attached to a force plate. PF generated during each PU was normalized to body weight (BW). There was no significant difference in PF generated between grips (P = 0.158) but there were significant differences in the PF generated over the course of 10 repetitions (P<0.001) and between the APU and UPU groups (P<0.001). On average the APU group lifted 114% of their BW and the UPU group lifted 151% of their BW.

KEY WORDS: Upper extremity, strength training, chin-up

INTRODUCTION: The pull-up is a common exercise used to measure upper body strength in physical fitness testing (Franks & Safrit, 1999). It is utilized by the military and presidential fitness testing in order to classify participants based on normative data in upper body strength (“The President’s Challenge,” 1993, Zielinski, 2010, “Enlisted Opportunities,” 2009). This exercise has also become a popular part of high intensity muscular endurance training programs, like CrossFit, in the United States. Many beginners of these new fitness training programs and participants in physical fitness tests cannot initially perform unassisted pull-ups and require assistance. Performing this exercise is particularly difficult for people that have a heavier body mass. In order to successfully perform an unassisted pull-up, lifters must overcome the entire body weight to perform a complete pull-up making it especially difficult for people with a heavier body mass (Romain & Mahar, 2001).
Assistance can take many forms such as using a lat-pull down machine instead of performing pull-ups, performing pull-ups on a spotting machine (the machine provides a counter weight to assist the lifter), using elastic bands, or using an individual spotter (manual spotting). The benefit of using machines is they allow the exact training load to be known by the lifter. However, machines are expensive and my not be available. The use of elastic bands and/or a spotter are cheaper and the typical means of allowing people to perform pull-ups. Unfortunately, these methods do not allow for quantification of the load experienced during training. This study focused on quantifying the load experienced in males while performing pull-ups with and without the assistance of a spotter using both pronated and supinated handgrips.

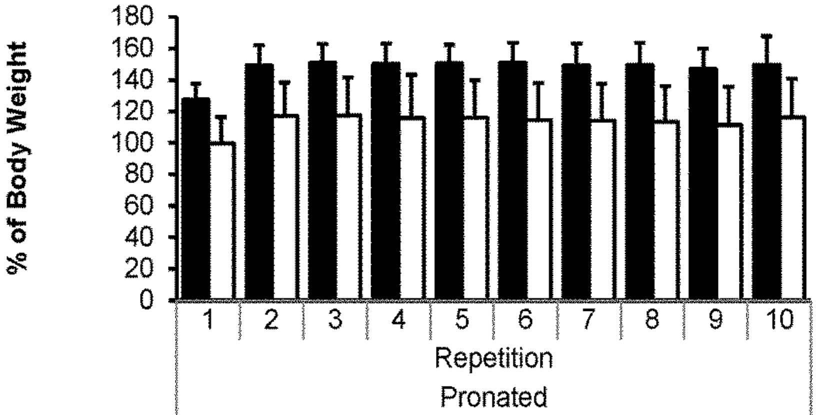
METHODS: This study was approved by the University’s Institutional Review Board. Participants were recruited from the University of Central Arkansas. Twenty-five males (mean ± SD: age= 23 ± 3 y; height= 180 ± 6 cm; weight= 88 ± 14 kg) participated in the study. All participants were, at the minimum, recreationally active and participated in strength training. Each participant completed an informed consent, PARQ, and medical history prior to participating in the study. Participants were categorized into two groups: those who could perform 10 pull-ups unassisted (N=13) and those who could not (N=12).
Prior to performing the pull-ups, participants warmed up on a cycle ergometer for five minutes at a speed and resistance of their own choosing followed by performing 10 push-ups and 20 jumping jacks. After warming up participants performed a set of 10 repetitions of pronated grip and supinated grip pull-ups with four minutes rest between sets. The number of repetitions was selected based upon the guidelines set forth by the American College of Sports Medicine (Pescatello & Riebe, 2014).

The assisted pull-up group had a spotter during both pull-up conditions. The order of grip was randomized between participants. Grip width was self-selected. Rate of movement was also self-selected; however, kipping, or other excessive swinging movements, were not allowed. Participants' form during the pull-ups was monitored by a certified strength and conditioning coach. Average repetition frequency was assessed after completion of the study by measuring the time between peak forces. While there was some variance, most participants completed each repetition in approximately two seconds (unassisted: 1.9 ± 0.4 s pronated and supinated; assisted: 1.9 ± 0.2s pronated, 1.8 ± 0.3 s supinated).

Participants performing the assisted pull-ups received spotting. Their feet were supported by a spotter so they could push off of the spotter and reduce the force needed to be generated by their upper body. Thus the amount of assistance was lifter chosen and not spotter chosen. The pull-up bar apparatus was constructed so that it could be securely attached to a force plate (Roughdeck-16960, Rice Lake Weighing Systems, Rice Lake, WI). The spotter was located away from the force plate so that any force exerted on the spotter by the lifters' legs would not be recorded.

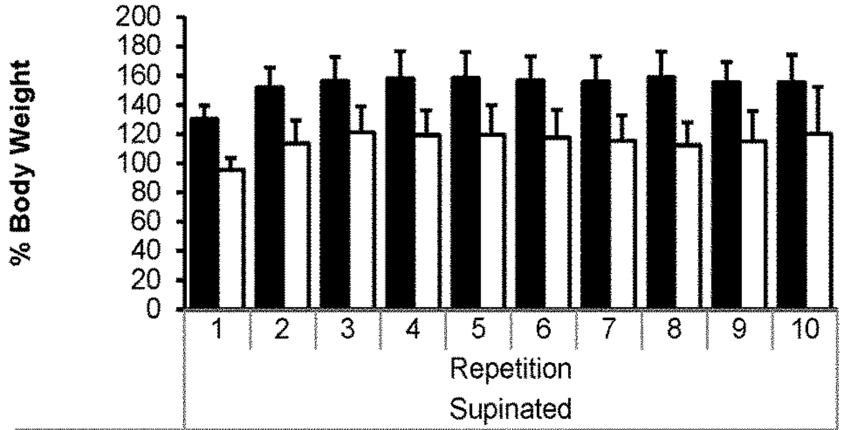
Force data were recorded using Labview software (National Instruments, Austin, TX) and evaluated using MatLab software (Mathworks, Natick, MA). Data were collected at 2000 Hz and smoothed with a fourth order, low pass Butterworth filter (cutoff frequency 20 Hz). Peak force, the greatest force generated during each repetition, was normalized to the body weight of each participant. A 2x2x10 (group x grip x repetition) ANOVA with repeated measures on the second and third variables was performed to evaluate the difference in peak force experienced during the pull-ups. Alpha level was set at 0.05. Upon reviewing the data, it was determined to perform pairwise comparisons when significant ANOVA values were found as opposed to post hoc tests due to the number of comparisons that would need to be made. It was determined to compare only the first repetition to the other repetitions of the set using least significant difference (LSD) comparisons. Statistical analysis was performed using PASW statistical software (Version 17, IBM, Armonk, NY).

RESULTS: There was no significant difference in peak force experienced between grips ($P = 0.158$) but there were significant differences in the peak force experienced over the course of the ten repetitions ($P<0.001$) and between the unassisted and assisted groups ($P<0.001$) (Figures 1 & 2). On average, the unassisted group experienced a peak force of 148% of their body weight using a pronated grip and 154% using a supinated grip. Least significant difference comparisons showed that the first repetition was significantly lower ($P<.001$) than all other repetitions. The assisted group experienced a peak force of 114% of their body weight using a pronated grip and 115% using a supinated grip.



	1	2	3	4	5	6	7	8	9	10
■Unassisted	128	149	151	150	151	151	149	150	147	150
□Assisted	100	117	117	116	116	115	114	113	111	116

Figure 1: Peak force experienced during a set of 10 repetitions of assisted and unassisted pull-ups using a pronated grip. Significant difference (P < .001) between groups.



	1	2	3	4	5	6	7	8	9	10
■Unassisted	130	152	156	158	158	157	156	159	155	156
□Assisted	95	114	121	119	120	118	116	112	115	120

Figure 2: Peak force experienced during a set of 10 repetitions of assisted and unassisted pull-ups using a supinated grip. Significant difference (P < .001) between groups.

DISCUSSION: This study was primarily descriptive in nature and similar to several recent studies that have tried to quantify unknown loads during resistance training (Andre, Fry, & Bradford, 2013; McMaster, Cronin, & McGuigan, 2010; Neely, Carter, & Terry, 2010; Shoepe, Rairez, & Almestedt, 2010; Wallace, Winchester, & McGuigan, 2006). The purpose of this study was to evaluate the differences in peak forces generated by males performing assisted and unassisted pull-ups. It was decided to evaluate the peak force generated because this typically occurs immediately prior to the "sticking point" of a lift. The sticking point is believed to be the weakest point in the concentric phase which an attempt will potentially fail (Lander et al., 1985). This typically occurs because of poor mechanical advantage created by the position of the limbs (Elliott, Wilson, & Kerr, 1989). Thus, it is advantageous to generate a large peak force to generate enough inertia to overcome the sticking point. The peak force experienced during each repetition was a combination of the lifter's bodyweight, amount of assistance (if provided), and the inertia generated. All lifters experienced less peak force during the first repetition of the set due to starting in a static "dead hang" where they did not have to overcome the inertia generated during the eccentric phase and did not elicit the stretch shortening cycle. The inertial component may have been better accounted for if a set rate of movement had been required, but the average rate of movement was very similar without external control. Additionally, the goal of this study was to quantify what peak forces are generated in normal training conditions by recreational lifters and most lifters do not use external temporal regulation.

From the gathered data, it is observed that the assisted pull-up group did generate a lower peak force over 10 repetitions as one would expect. While the exact amount of assistance was not quantified, we speculate that the difference in peak force experienced between the two groups would be representative of the average amount of assistance provided. As mentioned previously, the force generated would be a combination of body weight, inertia, and assistance (if provided). By normalizing to body weight some of the variation in forces generated has been accounted for, and due to the similar repetition frequency observed between the groups, it may be assumed that the inertia components were similar. However, these assumptions would need to be verified with future research.

The decision to perform assisted pull-ups as part of a training regimen would be dependent upon the goals of the individual. If the focus is muscle endurance or hypertrophy, an adequate number of repetitions must be completed to elicit appropriate hormonal and metabolic responses (Crewther, Cronin, Keogh, 2006; Crewther et al. 2006) even if the intensity is not maximal. In these cases, performance of assisted pull-ups would be warranted even though the intensity is lower due.

CONCLUSION: The knowledge that an average male will lift approximately 60% of their body weight (40% reduction compared to an unassisted lifter) can help coaches quantify their athletes' lifting if pull-ups are part of their regimen. This weight could also be used as an initial training load if machines are available.

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