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The effect of a familiarisation period on subsequent strength gain

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Abstract

Untrained subjects can display diverse strength gain following an identical period of resistance exercise. In this investigation, 28 untrained males completed 16-weeks of resistance exercise, comprising 4-weeks familiarisation, and 12-weeks of heavy-load (80–85%) activity. High and low responders were identified by the Δ1RM (Δ one repetition maximum) observed following familiarisation (25.1 ± 1.4%, 9.5 ± 1.4%, $P < 0.0001$) and differences in electromyographic root mean square amplitude (ΔEMGRMS 29.5 ± 8.3%, 2.4 ± 6.0%, $P = 0.0140$), and habitual and occupational activity patterns were observed between these respective groups. The strength gain ($P < 0.0001$) observed within high (29.6 ± 1.7%) and low (31.4 ± 2.7%) responding groups was similar during the heavy-load phase, yet ΔEMGRMS increased ($P = 0.0048$) only in low responders (31.5 ± 9.3%). Retrospectively, differences ($P < 0.0001$) in baseline 1RM strength of high- (19.7 ± 0.9 kg) and low-responding (15.6 ± 0.7 kg) groups were identified, and a strong negative correlation with Δ1RM after 16-weeks ($r 2 = -0.85$) was observed. As such, baseline 1RM strength provided a strong predicative measure of strength adaptation. The ΔEMGRMS suggests strength variability within high and low responders may be attributed to neural adaptation. However, differences in habitual endurance and occupational physical activity suggests one should consider screening not only recent resistance training, but also other modes of physical activity during participant recruitment.

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The effect of a familiarisation period on subsequent strength gain

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Abstract

Untrained subjects can display diverse strength gain following an identical period of resistance exercise. In this investigation, twenty-eight untrained males completed 16-weeks of resistance exercise, comprising 4-weeks familiarisation, and 12-weeks of heavy-load (80-85%) activity. High and low responders were identified by the Δ1RM observed following familiarisation (25.1 ±1.4%, 9.5 ±1.4%, $p<0.0001$) and differences in electromyographic root mean square amplitude (ΔEMG_{RMS} 29.5 ±8.3%, 2.4 ±6.0%, $p=0.0140$), and habitual and occupational activity patterns were observed between these respective groups. The strength gain ($p<0.0001$) observed within high (29.6 ±1.7%) and low (31.4 ±2.7%) responding groups was similar during the heavy-load phase, yet ΔEMG_{RMS} increased ($p=0.0048$) only in low responders (31.5 ±9.3%). Retrospectively, differences ($p<0.0001$) in baseline 1RM strength of high- (19.7 ±0.9 kg) and low-responding (15.6 ±0.7 kg) groups were identified, and a strong negative correlation with Δ1RM after 16-weeks (r^2= -0.85) was observed. As such, baseline 1RM strength provided a strong predicative measure of strength adaptation. The ΔEMG_{RMS} suggests strength variability within high and low responders may be attributed to neural adaptation. However, differences in habitual endurance and occupational physical activity suggests one should consider screening not only recent resistance training, but also other modes of physical activity during subject recruitment.

1.0 Introduction

Pre-training status (phenotype) significantly influences the strength gain observed during resistance training, with some individuals being very responsive, whilst others show little strength adaptation (Ahtiainen *et al.*, 2004; Alen *et al.*, 1984). Significant inter-participant variability is however also observed within an untrained cohort, with differences of >150% in one repetition maximum (1RM) strength gain reported between the highest, and lowest responders following a period of identical training (Hubal *et al.*, 2005). This is a characteristic of all forms of physiological adaptation, and, in the case of resistance training, adaptation responsiveness may even be genetically determined (Clarkson *et al.*, 2005; Pescatello *et al.*, 2006; Thomis *et al.*, 1998). Thus, outcomes from training studies can be masked or exaggerated if participant selection and treatment allocation have a bias favouring low or high responders (respectively) that may confound data interpretation.

One solution used to address differences in adaptation responsiveness has involved grouping participants on the basis of training history (Campos *et al.*, 2002; Hubal *et al.*, 2005; Munn *et al.*, 2005), yet inter-participant variability in strength gain remained high (Hubal *et al.*, 2005). Others have grouped participants according to similarities in morphological or baseline strength attributes (Folland *et al.*, 2002; Kraemer *et al.*, 2004; Moss *et al.*, 1997). However, the effectiveness of this strategy has not been evaluated.

The resistance exercise literature has commonly defined participants as untrained based on the absence of resistance training experience for a period of 6–12 months (Ratamess *et al.*, 2009). However this definition fails to consider the impact that occupational, habitual and endurance-related activities may have on strength adaptation. For example, concurrent strength and endurance training may interfere with strength adaptation (Hickson, 1980) (Bell *et al.*, 2000; Dudley & Djamil, 1985; Hennessey & Watson, 1994). It is therefore possible that strength adaptations may be influenced by concurrent (habitual and occupational) endurance activity patterns.

In this investigation, the adaptations observed following a period of resistance exercise and the extent of inter-participant variability were examined. A controlled period of resistance exercise can be applied prior to an experimental intervention during a familiarisation period. Indeed, previous investigations have incorporated familiarisation periods of 1-4 weeks (Campos *et al.*, 2002; Dudley *et al.*, 1991). A familiarisation period may enable better control over any confounding influences that may impact upon strength adaptation; however the effectiveness of this research design element has never been formally evaluated. Thus, the principal focus of this experiment therefore centred upon how participants identified as high and low responders to resistance training would adapt to an extended resistance training programme.

This is potentially an important topic since, to the best of our knowledge, no resistance training experiments exist in which participant responsiveness to a resistance training stimuli has formed an integral part of the experimental design. Yet, it is well known that an evaluation of the effectiveness of different training regimens is very difficult when the pre-training status of research participants varies across treatment groups (Hakkinen, 1985). Considering the widely adopted approach to group participants with respect to their strength capacities (Folland *et al.*, 2002; Kraemer *et al.*, 2004; Moss *et al.*, 1997), this experiment therefore retrospectively evaluated the effectiveness of grouping participants according to variations in baseline strength. In line with the literature, participant's recent resistance exercise histories were screened during recruitment. Endurance activity patterns did not however form any part of the inclusion criteria. This was an intentional consideration in order to evaluate the third aim of this experiment and examine the effect of habitual endurance-based exercise and physical activity patterns on adaptation responses observed during resistance training.

2.0 Methods

Twenty-eight untrained males, who had not participated in resistance exercise for a minimum of six months, completed this project. All participants provided written, informed consent and completed a standard physical activity and medical history questionnaire utilised within our laboratory formulated from validated questionnaires (Chisholm *et al.*, 1978; Ferris, 1978; Salis *et al.*, 1985; Thomas *et al.*, 1992). Procedures were approved by the Human Ethics Research Committee (University of Wollongong).

All participants were first familiarised with resistance exercise for 4-weeks, training three times per week. Unilateral elbow flexions and extensions of the dominant limb, were performed through a 100° range of motion (60° flexion - 160° extension) from a supine position, using a custom-built apparatus instrumented with a load cell (Applied Measurement, X-TRAN, 51W-1kN, Eastwood, Australia) and shaft encoder (E6C2-CWZ6C-1000, Omron, Minato-ku, Tokyo, Japan) (Figure 1). The experimental position was chosen to isolate the elbow flexor muscle group by restricting lumbar extension and auxiliary muscle activation. Resistance loads were increased from 50% to 80% of one repetition maximum (1RM) over these four weeks. Participants completed four sets of exercise in each session, a fixed number of repetitions per set (15 and 12) were completed in weeks one and two, while participants trained to task failure in weeks three and four. The purpose of this training was to enable an evaluation of participant responsiveness, from changes in 1RM strength. Participants were classified as either high or low responders to the adaptation stimulus on the basis of strength change, and their subsequent adaptations to a further 12 weeks of heavy-load resistance training were recorded. The greatest separation in relative strength gain was observed between the 25th (≤15.8%) and 75th (≥17.9%) percentiles. Thus, individuals who achieved a 1RM strength gain ≥17.9% were defined as high responders, and all other participants were deemed to be low responders. This classification also resulted in an equal number of high (*N*=14) and low responders (*N*=14), who were counterbalanced across three different training groups for a further 12-weeks of heavy-load (85% 1RM) resistance exercise. The three treatment groups were differentiated by elbow flexion movement speed and total work, subjects either i) trained to task failure using slow (2 s) flexion and (2 s) extension phases of contraction, ii) trained using maximal acceleration during flexion and a slow (2 s) extension, or iii) trained to maximal acceleration during flexion and extension. Participants were assisted during controlled periods of contraction with a digital metronome (Boss TU-80, Roland Corporation, CA, USA) and differences in contraction velocity were examined retrospectively from data collected by the shaft encoder. Subjects within the two groups performing muscle contractions including maximal acceleration were instructed to perform only four repetitions per set, whilst the first group using slow (2 s) phases of contraction trained to task failure, completing approximately 6 repetitions per set. Thus, groups performing rapid muscle contractions performed approximately 30% less work than the task failure resistance exercise group.

INSERT FIGURE 1 ABOUT HERE

Dominant limb elbow flexor 1RM strength was assessed in the experimental position at baseline (week 0), after familiarisation (week 4) and in weeks 8, 12 and 16 of heavy-load resistance training. Strength was determined as the highest successful repetition to the closest 0.25 kg. An average of 5.2 SD 2.3 attempts, were completed before 1RM was achieved, with a minimum 2-min rest between successive attempts.

In addition to the main hypothesis, electromyographic root mean square amplitude (EMG_{RMS}) from agonist, antagonist and synergist muscle groups were collected during 1RM tests at week 0, 4 and 16. Surface electrodes (Ag/AgCL contact diameter 15 mm) were adhered to the *biceps brachii* midway between the acromion process and elbow crease, and central to the muscle belly of the medial head of *triceps brachii*. Movement of the proximal radioulnar joint was controlled by maintaining the forearm in supination, and shoulder stabilisation was assessed by monitoring EMG_{RMS} amplitude via surface electrodes located on the *anterior deltoid* 40 mm below the clavicle, and on the *upper trapezius*, along the ridge of the shoulder, halfway between the cervical spine and the acromion.

Electrode positions were marked using henna dye and maintained throughout training. Electromyographic signals were pre-amplified with a low-frequency cut-off (3 Hz), amplified (1000×), and high- (10 Hz) and low- (500 Hz) band pass filtered (Neurolog 844, 820, 144, 135, Digitimer Neurolog, Hertfordshire, U.K.). Data were collected at 2000 Hz, and processed via an analogue to digital converter (Power 1401, Cambridge Electronic Design, Cambridge, U.K.) using Spike 2 software (Ver 5.13, Cambridge Electronic Design, Cambridge, U.K.). EMG_{RMS} amplitudes (mV) were analysed using Spike 2, via a series of 250 ms windows with a 50% overlap, scrolling the duration of the 1RM, and normalised to baseline values within participants.

Elbow flexor cross-sectional area was measured by an experienced radiologist for 13 high and 12 low responders at the end of weeks 4 and 16. Muscle cross-sectional area was not assessed at baseline as it is well established that 4 weeks of resistance exercise is insufficient to induce a change in muscle cross-sectional area (Abe *et al.*, 2000; Moritani & DeVries, 1979; Staron *et al.*, 1994). A total of 46 muscle slices were recorded (thickness 6.35 mm, with 1 mm inter-slice gap) using magnetic resonance imaging (MRI), Turbo Spin Echo, T2 images (1.5 T Philips Intera, Philips Healthcare, Da Best, Netherlands). Participants were supine for these scans, with the superior margin of the coil positioned level with the acromioclavicular joint. Imaging commenced at the superior portion of the humeral head, extending distally along the length of the muscle. The *biceps brachii* and *brachialis* muscles were traced using commercially available software (3D-Doctor, Able Software Corporation, Lexington, MA, U.S.A.), and cross-sectional area was calculated as the mean across seven images central to the muscle belly (slices 20-26).

A two-way repeated measures *ANOVA* determined group (high versus low responder), by time interactions. When significant interactions were detected, a *post hoc* Bonferroni correction for multiple comparisons was applied. A multiple regression examined 1RM strength gains relative to baseline 1RM strength, and the impact of participant responsiveness during familiarisation, on the subsequent 1RM strength gain observed after heavy-load resistance training. Physical activity questionnaire responses were ranked and analysed via a Mann Whitney *U*-test (Prism Ver. 5.00, GraphPad Software, San Diego California U.S.A.). Data are represented as means and standard errors of the means (±) unless stated otherwise (SD), with *alpha* set at $p<0.05$ for all statistical analyses.

3.0 Results

No significant difference was observed in the general characteristics of high and low responders in age (21.6 SD 4.4 and 25.9 SD 7.4 y), height (178.7 SD 7.8 and 180.2 SD 6.5 cm) or body mass (78.9 SD 13.3 and 81.3 SD 11.4 kg) respectively. Self-reported exercise histories differed significantly between high- and low-responding groups, suggesting that strength gains were inversely associated with endurance and occupational activity. Differences were observed in the number of high and low responders reporting habitual activity, (7 high, 13 low, $p=0.0149$), physically demanding employment (4 high, 9 low $p=0.0148$), frequency of vigorous endurance exercise (~1 × per week high, ~3 × per week low, $p=0.0035$), and recreational activity (~2-3 × per week high, ~4-6 × per week low, $p=0.0484$).

The strength gains observed during the 12 week heavy load training period (weeks 4-16) were similar across the three treatment groups (28.6 ±2.2%, 32.8 ±1.5% and 30.6 ±3.8%). Furthermore, similar strength gains were observed between high and low responders across the three treatment groups in weeks 8, 12 and 16 during heavy-load resistance training. Thus, since high and low responders were counterbalanced across groups, and significant differences in strength adaptation were not observed among the three regimens, the three groups were collapsed and herein we report a comparison of strength adaptation between 14 high and 14 low responders during the four week familiarisation and subsequent 12 week training periods.

Baseline 1RM strength loads were greater ($p<0.0001$) in low (19.7 ±0.9 kg), compared to high responders (15.6 ±0.7 kg). However, the high-responding group recorded a 25.1 ±1.4% increase in elbow flexor strength compared to a 9.5 ±1.6% in the low responders during familiarisation ($p<0.0001$) and, as such 1RM strength was similar between high- and low-responding groups in week four (Figure 2). In contrast, no responder group by time interaction ($p=0.1499$) was observed during heavy-load resistance training (weeks 8, 12 and 16), with high responders displaying a 29.6 ±1.7% and low responders a 31.4 ±2.7% increase in 1RM strength at week 16.

INSERT FIGURE 2 ABOUT HERE

The single best predictor of strength gain ($p<0.0001$) following the 16-week training period was each individuals baseline strength ($r^2= -0.85$, Figure 3), indicating that 1RM strength gains are greater amongst participants with initially low strength capabilities. Within the multiple regression, responsiveness to familiarisation (% Δ 1RM) also explained a significant ($p=0.0133$) proportion of the variance in 1RM strength following 16-weeks of training and increased the $r^2= -0.88$.

INSERT FIGURE 3 ABOUT HERE

Significant differences were observed in *biceps brachii* EMG_{RMS} amplitude following familiarisation ($p=0.0140$) and heavy-load ($p=0.0392$) training phases (Figure 4). After familiarisation, an increase in agonist EMG_{RMS} amplitude ($p=0.0036$) was observed in high responders, but remained unchanged in low responders ($p=0.6924$). In contrast, after heavy-load training, the agonist EMG_{RMS} amplitude for low responders increased ($p=0.0048$), yet remained unchanged in high responders ($p=0.4338$). An increase ($p=0.0247$) in *triceps brachii* EMG_{RMS} amplitude was observed in high- (42.1 ±12.0%) and low-responding (8.1 ±7.7%) groups during familiarisation, although the change observed in the high responders was greater (p=0.0016). In contrast, during the heavy-load training period *triceps brachii* EMG_{RMS} amplitude increased (p=0.0049) in both high (22.9 ±14.2%) and low (26.5 ±7.5%) responders, but no interaction was observed. No change in EMG_{RMS} amplitude was observed between or within groups for the *anterior deltoid* and *upper trapezius* after either training phase, (p≥0.05), suggesting participants successfully maintained shoulder joint stabilisation throughout assessment and training.

INSERT FIGURE 4 ABOUT HERE

Elbow flexor cross-sectional area (*biceps brachii* and *brachialis* combined) was similar between high (11.97 ±0.54 cm^2) and low responders (12.90 ±0.63 cm^2) at week four. Muscle size increased significantly (p<0.0001) in both high (10.8 ±1.6%) and low responders (9.0 ±2.1%) following the heavy-load training period (weeks 5-16), and no interaction was observed (p=0.7526).

4.0 Discussion

Three significant outcomes have emerged from this experiment. Firstly, baseline 1RM elbow flexion strength, and strength gains during the familiarisation period were significantly and negatively correlated with the strength gain observed during heavy-load resistance training. Secondly, while the strength adaptation for high and low responders was markedly different during familiarisation, no significant differences were observed prior to, or during the heavy-load training phase. Thus, the familiarisation period, appeared not only to identify the two responder types, but also helped to standardise the resistance training background of all participants upon which the heavy-load training phase was overlayed. Thirdly, we should recall that all participants in this investigation reported an absence of resistance training for at least 6-months on recruitment; screening recent resistance training history was therefore an inadequate tool for the estimation of 1RM strength gain in untrained participants.

Our results show a very strong inverse relationship (r^2= -0.85) between baseline 1RM strength and strength adaptation, suggesting that baseline strength is a critical phenotypic characteristic that should be considered when assigning participants to experimental groups, an approach frequently used by a number of investigators (Kraemer *et al.*, 2004; Moss *et al.*, 1997; Rooney *et al.*, 1994). Given that this investigation employed a simple elbow flexion open-kinetic single-joint movement with a training regimen specific to the 1RM assessment task, such a correlation may well have been anticipated (Thorstensson *et al.*, 1976). Contrary to our observations, much lower correlations (r^2= -0.30) between baseline 1RM elbow flexor strength and subsequent strength gain have been observed (Hubal *et al.*, 2005). Interestingly, Hubal *et al,* (20), also used an untrained cohort, however, in contrast to the current investigation, training was performed on the non-dominant limb, and training involved multiple resistance exercises, targeting both the elbow flexors and extensors as the agonist. The difference in training regimen, limb dominance, larger sample size (N=585) and mixed gender may have accounted for the lower correlation reported between baseline 1RM and subsequent strength gain for this single joint task. Furthermore, due to the specificity of our assessment and training regimen, it is entirely predictable that baseline strength may be correlated with subsequent strength gain. However, this relationship is reduced when training regimens are multi-joint and not directly associated to the assessment task (Hakkinen, 1985; Thorstensson *et al.*, 1976), and under these conditions, baseline strength scores may not be predictive of subsequent adaptation (Hakkinen, 1985).

To overcome this potential limitation some investigations have included a familiarisation period of resistance exercise, prior to the primary experimental stimulus (Campos *et al.*, 2002; Dudley *et al.*, 1991). However, in contrast to the current design, these preliminary phases were used only to standardise the pre-experimental training status of subjects, and were not used to balance adaptation responsiveness across experimental treatments. In our hands, the strength gain observed during the familiarisation period revealed a significant, but relatively small inverse relationship, increasing the predictive power of the multiple regression analysis from r^2= -0.85 to r^2= -0.88. Thus, although the strength gains observed in this investigation were consistent with the literature (Clarkson *et al.*, 2005; Hubal *et al.*, 2005; Pescatello *et al.*, 2006), the time-course of strength adaptation over the 16-week period of this investigation between responder groups was disparate. Indeed, a significant difference in strength gain was observed between high and low responders during familiarisation (~25% and ~10% respectively). In this investigation, a four-week familiarisation period was therefore an effective intervention that was shown to balance adaptation responses across the whole cohort and create a more homogenous group. The progressive loading during familiarisation, appeared therefore not only to identify the two responder types, but also helped to standardise the resistance training background upon which the 12-week training phase was overlayed.

In the subsequent 12-weeks of heavy load resistance training, no significant difference was observed in 1RM strength gain (~30% and ~31%), or muscle cross-sectional area (~11% and ~9%), between high and low responders respectively. Thus, after the 4-week familiarisation period both groups responded similarly to resistance training, suggesting that neural factors normally associated with early changes in strength, primarily contributed to the divergence in strength adaptation seen between the two groups within the 4-week familiarisation phase. This is indeed consistent with the current literature, and this variability highlights the difficulty one may have in attributing the adaptations observed to the resistance exercise program following short duration interventions (Carroll *et al.*, 2002; Fleck, 1999; Moritani & DeVries, 1979). This investigation has however shown that a four week familiarisation period prior to the commencement of experimental training, assists in obtaining more uniform adaptive responses.

Moreover, these early phase neural adaptations can significantly affect data interpretation in longer duration training interventions. Consider the findings of this investigation, if the 1RM strength gains in the familiarisation and 12-week resistance regimen periods had been pooled, we would have reported a significantly ($P<0.0001$) greater strength gain in high (~62%), compared to low responders (~44%) over the total 16-week period, when indeed the divergence in strength adaptation only occurred in the first four weeks. Thus, our results suggest that investigators conducting prolonged experimental training regimens should incorporate regular assessments to quantify adaptation responses, with particular emphasis placed upon those adaptations that occur early within a resistance training intervention.

The divergence in strength adaptation observed during the familiarisation period was also observed in EMG_{RMS} amplitude, with high-responders having a significantly greater increase in agonist (~30%) and antagonist (~40%) activation. In contrast, the change in agonist (~2.5%) and antagonist (~8%) EMG_{RMS} amplitude in low responders during familiarisation was significantly reduced. However, during the 12-week resistance training regimen an inverse response in agonist EMG_{RMS} was recorded, with low responders having a significantly greater increase in agonist EMG_{RMS} amplitude (~32%) compared to high responders (~6%). Thus, despite low responders also reporting no resistance exercise experience for at least six months, a load-dependent adaptation threshold was observed, with some participants requiring loading in excess of 80% of 1RM to illicit a significant strength adaptation, and a corresponding increase in electromyographic activity. Normally, this level of loading is required to see progression in resistance trained cohorts (Hakkinen *et al.*, 1985; Hakkinen *et al.*, 1987), well beyond the 40-50% of 1RM that has been shown to be effective in previously untrained individuals (Moore *et al.*, 2004).

Although responsiveness to a resistance training regimen will be in part genetically determined (Clarkson *et al.*, 2005; Pescatello *et al.*, 2006), it is significant that the low-responding participants in the current investigation reported markedly different levels of endurance physical activity and therefore initial training status. Initial training status from the continuum of untrained to elite-trained individuals contributes significantly to strength adaptation (Ahtiainen *et al.*, 2004; Ratamess *et al.*, 2009). However, an untrained cohort has been routinely defined as an absence of resistance training (6–12 months) experience (Ratamess *et al.*, 2009). This relatively narrow definition fails to consider other concurrent physical activity habits, and thus ignores the linkage between concurrent habitual exercise and resistance training responsiveness (Bell *et al.*, 2000; Dudley & Djamil, 1985; Hennessey & Watson, 1994; Hickson, 1980).

In the current investigation, physical activity questionnaires identified significantly increased levels of endurance and occupational activity within low-responding subjects. It is therefore possible that an interference effect was present within low-responding subjects if endurance activity patterns remained high during the resistance training intervention (Bell *et al.*, 2000; Dudley & Djamil, 1985; Hennessey & Watson, 1994; Hickson, 1980). However, strength adaptation was similar between high and low responding subjects during weeks 4-16. The strong inverse relationship observed between baseline 1RM strength and total 1RM strength gain after 16-weeks of resited activity therefore suggests that regardless of physical activity patterns, subjects possessing high initial 1RM strength capabilities did not increase their capacity during the relatively low-load familiarisation period. It is therefore perhaps significant that endurance-trained, like strength-trained individuals have been shown to display increased force production capabilities relative to muscle cross-sectional area, and an increased capacity to voluntarily activate skeletal muscle (Alway *et al.*, 1996; Castro *et al.*, 1995; Del Balso & Cafarelli, 2007). If such differences were indeed evident within the cohort recruited for this investigation, it would support the contention that relatively low resistance loads were insufficient to induce a neuromuscular activation levels required to elicit significant strength adaptation. In addition, one should consider that less active individuals may experience increased neuromuscular activation to develop intra-muscular coordination during skill learning (Rutherford & Jones, 1986). Thus, if one aims to recruit a homogenous group, based on our findings the characterisation of individuals as untrained must include not only resistance exercise history, but also formally consider endurance and occupational experience.

5.0 Conclusion

From this experiment, it was concluded that the design of resistance training studies requires careful consideration to avoid the introduction of preventable bias in the potential adaptation responsiveness of untrained subjects within one or more treatment conditions. Baseline 1RM strength was strongly correlated with the time-course of subsequent strength adaptation during a 4-week familiarisation period of progressive resistance exercise. Significantly, adaptation responsiveness was normalised across the cohort following the familiarisation period, thus resistance exercise interventions which aim to minimise inter-subject variability should consider an evaluation of pre-experimental training status, and or the inclusion of a familiarisation period, prior to experimental training.

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Figure legends

Figure 1 Set-up demonstrating the experimental position. Dominant limb elbow flexion was performed through a 100° range of motion, with end points marked by via guide bars positioned at 60° of flexion - 160° of extension.

Figure 2 Trained limb, one repetition maximum (kg) in high and low responders. Strength assessments were performed at baseline (week 0), following familiarisation (week 4), and during weeks 8, 12, and 16 of a heavy-load resistance training regimen. Data represent means ± SE. †= significant between group difference in baseline one repetition maximum strength (P<0.05); ‡= significant between group difference in strength gain during familiarisation (P<0.05).

Figure 3 The relationship observed between baseline strength and strength adaptation over a 16-week resistance training regimen (r^2 = -0.85). Data are co-ordinates for high- and low-responding participants.

Figure 4 Electromyographic root mean square amplitude (%) recorded from the trained limb *biceps brachii* during one repetition maximum elbow flexion after familiarisation and heavy-load training in high and low responders. Data were normalised within participants to baseline values and represent the mean ± SE. †= significant difference from baseline (P<0.05); ‡= significant difference from familiarisation (P<0.05); §= significant difference between the high- and low-responding groups (P<0.05).

Figure 1

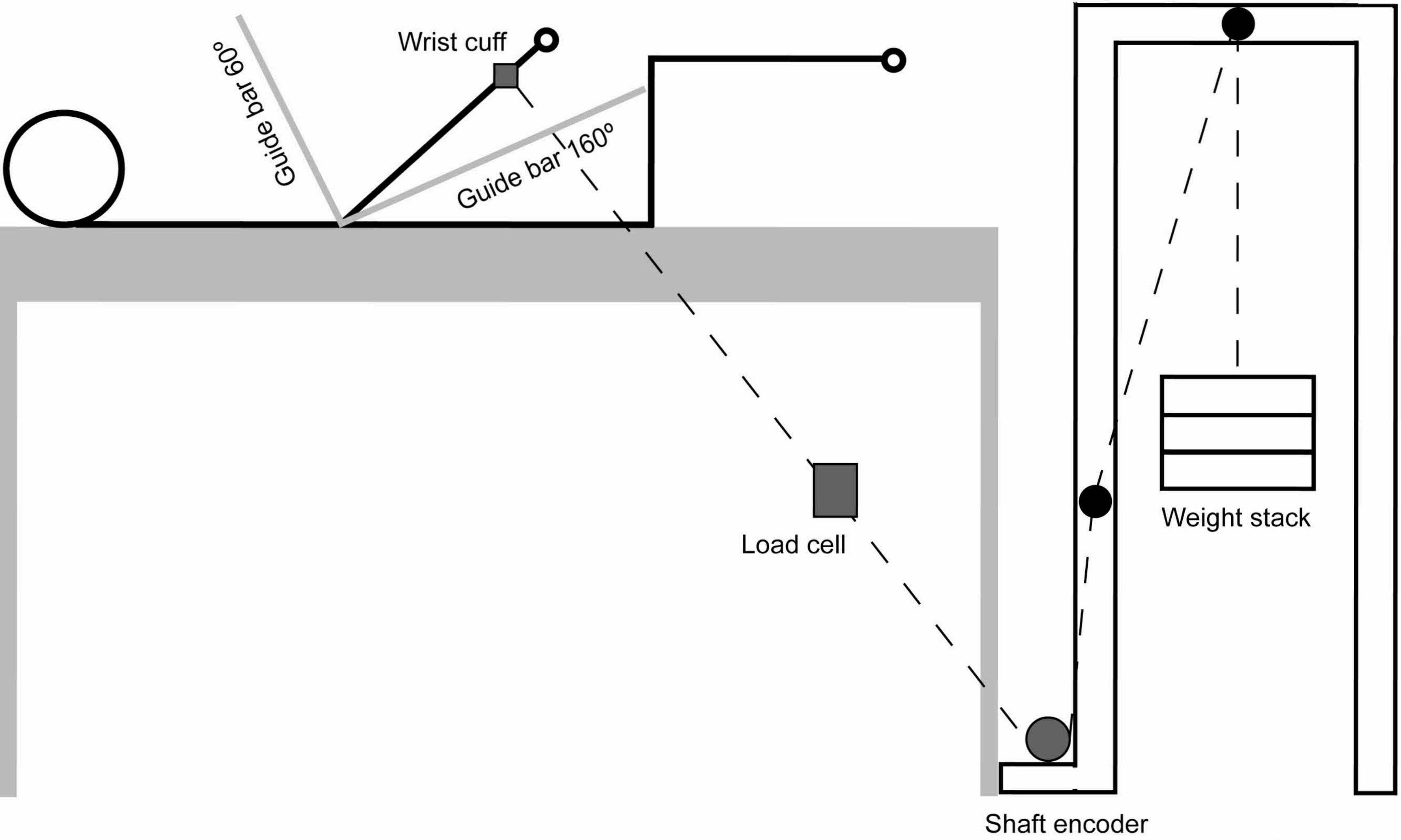

Wrist cuff
Guide bar 60º
Guide bar 160º
Load cell
Weight stack
Shaft encoder

Figure 2

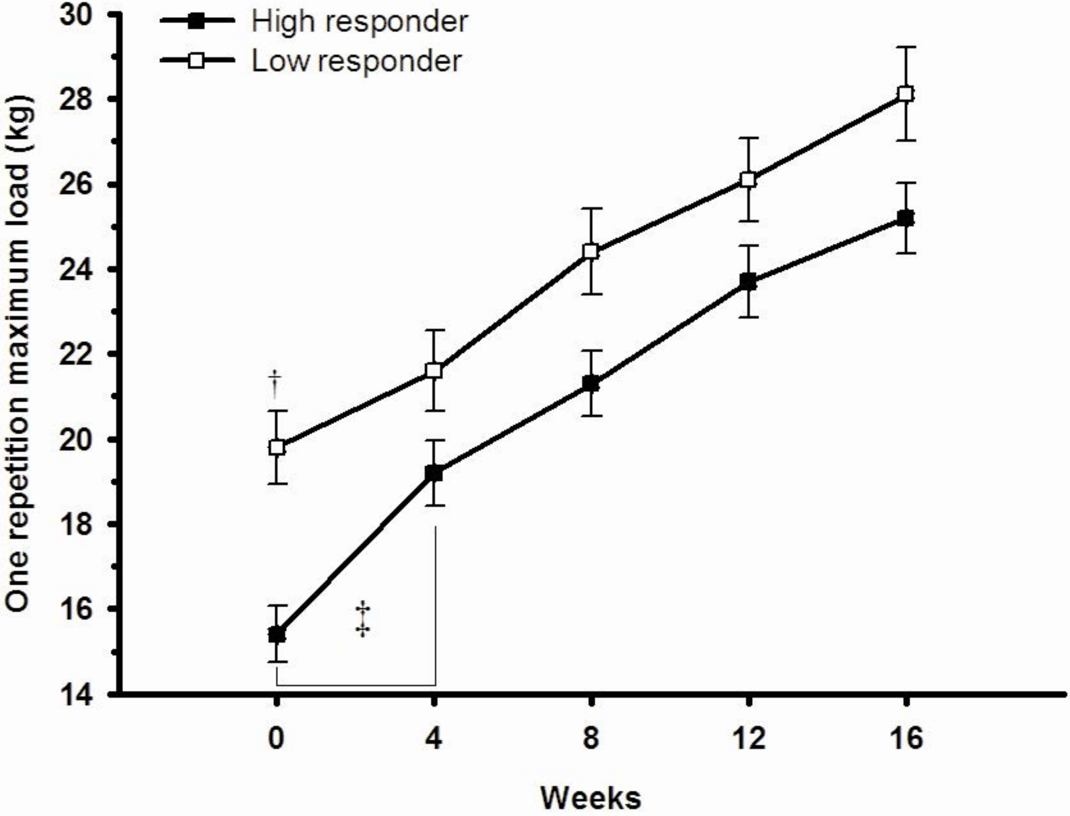
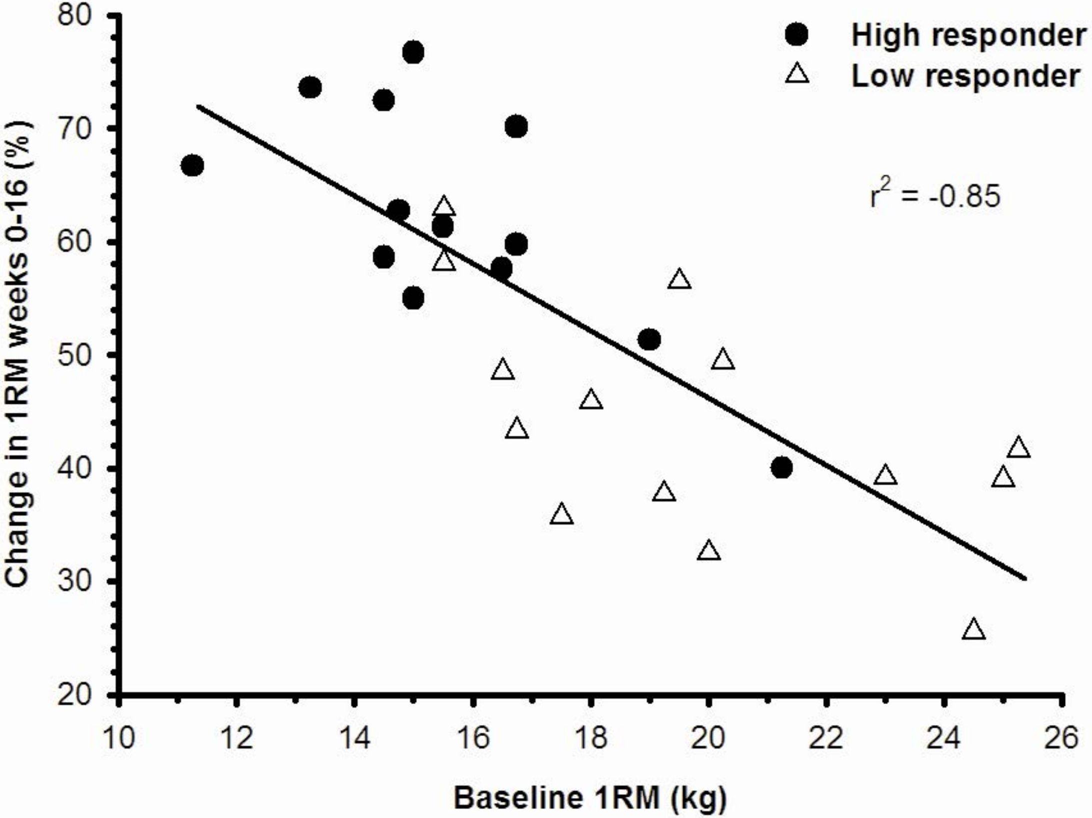
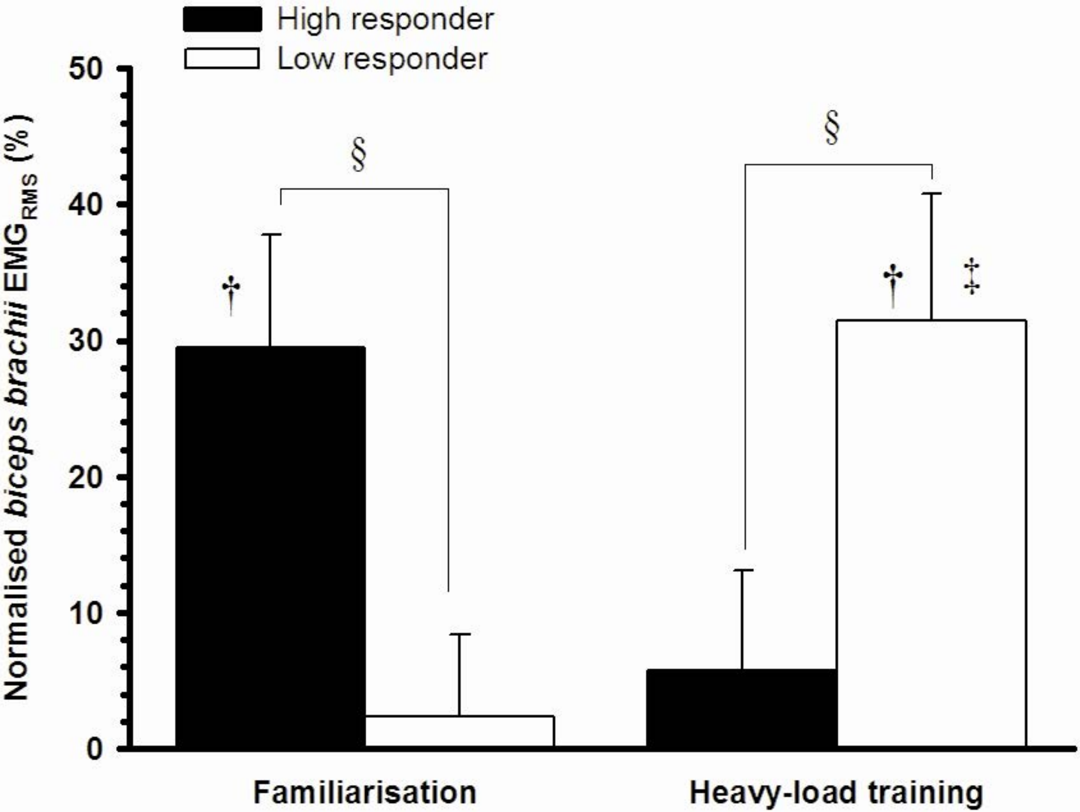

High responder
Low responder
One repetition maximum load (kg)
30
28
26
24
22
20
18
16
14
†
‡
0
4
8
12
16
Weeks

Figure 3



80
70
60
50
40
30
20
Change in 1RM weeks 0-16 (%)
10
12
14
16
18
20
22
24
26
Baseline 1RM (kg)
● High responder
△ Low responder
r^2 = -0.85

Figure 4


■ High responder
□ Low responder
Normalised *biceps brachii* EMG$_{RMS}$ (%)
50
40
30
20
10
0
§
§
†
†
‡
Familiarisation
Heavy-load training