Original Research

Resistance Training Recovery: Considerations for Single vs. Multi-joint Movements and Upper vs. Lower Body Muscles

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ABSTRACT

International Journal of Exercise Science 8(1) : 85-96, 2015. This study examined muscle recovery patterns between single-joint (SJ) versus multi-joint (MJ), and upper-body (UB) versus lower-body (LB) exercises and the utility of perceptual measures (ratings of perceived exertion (RPE) and perceived recovery scale (PRS)) to assess recovery status. A 10 rep max (10-RM) was determined for 6 SJ and 4 MJ exercises (5 UB and 5 LB) for male recreational weightlifters (n = 10). Participants completed a baseline protocol including 8 repetitions at 85% of 10-RM followed by a set to failure with 100% of 10-RM. In a counter-balanced crossover design, participants returned at 24 or 48 h to repeat the protocol. PRS and RPE were assessed following the first and second sets of each exercise respectively. Wilcoxon matched pair signed-rank tests determined performance improved ($p < 0.05$) for every lift type category from 24 to 48 h, but the only difference in Δ repetitions from baseline at the same time point was between MJ (-1.7 ± 1.5 repetitions) and SJ (-0.5 ± 1.8 repetitions) at 24 h ($p = 0.037$). Higher RPE and lower PRS estimations ($p < 0.05$) support the utility of perceptual measures to gauge recovery as the only between group differences were also found between MJ and SJ at 24 h. Eighty percent of participants completed within 1 repetition of baseline for all exercises at 48 h except bench press (70%) and deadlift (60%); suggesting 72 h of recovery should be implemented for multi-joint barbell lifts targeting the same muscle groups in slower recovering lifters.

KEY WORDS: Weight training, RPE, perceived recovery scale, programming design

INTRODUCTION

Research indicates 1-7 days between resistance training exercise bouts may be needed for replication of previous performance (4, 5, 9-11, 13, 15, 17, 18). As general guidelines, the National Strength and Conditioning Association (NSCA) states that increased recovery time is needed between heavy lifting days and that upper body musculatures recovers faster than lower body musculature and single-joint lifts require less recovery time than multi-joint lifts (16 p.389). However, a careful review of the literature cited in the NSCA guidelines reveals most of the references are based on anecdotal evidence in older review papers or other textbooks and no quantitative evidence of recovery patterns were collected in the investigations cited supporting upper body versus lower body recovery (6) or single versus multi-

Table 1. Comparisons for lifting protocols between the current study, McLester et al. (15), and Jones et al. (8). Lifts include barbell bench press (BP), dead lift (DL), military dumbbell press (MP), leg press (LP), knee extension (KE), machine chest fly (CF), tricep extension (TE), dumbbell side raises (SR), hip adduction (HipAD), hip abduction (HipAB), lat pull down (LAT), bicep curl (BC), and leg curl (LC).

	Current Study	**McLester et al. (15)**	**Jones et al. (8)**
n	10	10	10 tested twice
Exercises performed	BP, DL, MP, LP, KE, CF, TE, SR, HipAD/AB	BP, SR, TE, LP, BC, LAT, LC, KE	BP, TE, LP, BC, LAT, LC
Sets completed per exercise/total sets	2/20	3/24	3/18
Reps completed per set	Set 1 = 8 Set 2 = voluntary failure	Voluntary failure every set	Voluntary failure every set
Time between exercises	90 seconds	30 seconds – 1 min	2 min
Time between sets	2 min	30 seconds – 1 min	2 min
Intensity (% 10RM)	Set 1 = 85% of 10RM Set 2 = 10RM	All sets = 10RM	All sets = 10RM
Recovery time (h)	24, 48	24, 48, 72, 96	48, 72, 96, 120

joint lift recovery (20). Recent investigations have sought to quantitatively determine the number of days needed for recovery to occur (8, 15). While these investigations have extended the knowledge concerning lifting recovery as a whole, they have not delineated if discrepancies exist between multi-joint, single-joint, upper body, and lower body.

Studies using repetitions to failure as a performance measure show recreational weightlifters are unlikely to be recovered at 24 hours (h), but show significant variance at 48 and 72 h, which may possibly be attributed to the inter-individual variability of delayed onset muscle soreness (DOMS) which typically peaks between 24-72 h (2, 8, 15, 25). In addition to a general consideration for DOMS (2, 8, 15, 24) the lifting protocols incorporated in previous studies likely affects quantitative evaluation for determining optimal time between lifting sessions. McLester et al. (15) and Jones et al. (8) both examined overall recovery times after resistance training (3 sets of 10 repetitions) repeated at 24, 48, 72, 96, and 120 h to determine time needed to return or exceed baseline performance following a full body workout. A limitation in interpreting these studies is that while McLester et al. (15) used 8 total and Jones et al. (8) used 6 different exercises (Table 1) both examined recovery in terms of differences in total repetitions.

Neither study reported recovery patterns based on individual exercises or single (SJ) versus multi-joint movements (MJ) or upper body (UB) versus lower body (LB) muscle groups which are key considerations when programing lifting sessions.

Determining ideal recovery time allows the athlete to initiate a subsequent training bout as soon as possible, limit detraining and optimize training volume, while avoiding overtraining to maximize training adaptations. It is plausible that recovery time for LB lifts may be shorter than UB exercises as the legs are involved in ambulatory tasks during daily living possibly leading to increased blood flow (23). Additionally, recovery time between lifting bouts may need to be extended for MJ core exercises such as bench press or squat versus SJ secondary exercises such as triceps or knee extensions as more total musculature is recruited and greater motor control is likely required during MJ lifts (16). Therefore the current study quantified muscle recovery patterns between SJ versus MJ, and UB versus LB exercises at 24 and 48 h. A secondary objective was to examine the efficacy to self-evaluate recovery using the classic perceptual subject ratings of perceived exertion scale (RPE) (22) and the more novel perceived recovery scale (PRS) (14).

METHODS

Participants

Ten recreationally strength trained college age males (26 ± 6 years) served as participants and all were over the age of 18 years old. All provided written consent prior to testing. Participants were excluded if they reported completing fewer than 3 resistance training sessions per week on average for the previous 12 weeks, were unfamiliar with any exercises incorporated in this investigation, or were not categorized as "low risk" based on PAR-Q and risk factor stratification questionnaire (1). Nine participants reported lifting ≥ 4 times per week and the remaining participant reported lifting 3+ times per week. Height (Stadiometer, Betco, Webb City, MO) and weight (BWB800, Tanita Corps, Japan) were assessed and body fat was estimated using a 3 site (chest, abdomen, thigh) skin fold assessment (Lange Calipers, Cambridge, MD, USA) (19). Height, weight, and percent body fat were (176 ± 6 cm, 83.1 ± 8.2 kg, 11.0 ± 3.0%) respectively. This study was approved by the local university's Institutional Review Board.

Protocol

A 10 repetition maximum (10-RM) was determined for 10 exercises during an initial session. Participants reported 5-7 days later for a baseline trial during which they completed 2 sets on the same 10 exercises. Eight repetitions (reps) at an intensity equal to 85% of their 10-RM was completed during the first set for each exercise. The second set was completed with 100% of 10-RM and participants lifted to failure. The purpose of the first set was to induce standardized fatigue before the subsequent set to failure. The protocol was replicated during two additional sessions with days of rest (either 24 or 48h) between the next two lifting sessions serving as the independent variable. A counter-balanced crossover design was used. Half of the participants repeated their workout 24 h after the baseline session and rested for 48 h before their fourth and final session (e.g. baseline Monday, 24 h session on Tuesday, and 48 h session on Thursday). The other half completed their third session 48 h after baseline testing and their fourth and final session 24 h later (e.g. baseline Monday, 48 h session on Wednesday, and 24 h session on Thursday). Participants were instructed to refrain from other exercise, alcohol, and to maintain regular diet and sleeping patterns from 48 h prior to their baseline testing session until completion of the study.

A protocol similar to that incorporated by McLester et al. (15) was used to determine the 10-RM for each exercise and establish weight to be lifted during baseline and experimental trials. Five to seven days before the baseline session, a 10-RM was obtained for each exercise (described below) in the lifting protocol. Participants started with a light 15 rep warm up. Once the warm up was completed, participants estimated their 10 RM. Participants lifted to fatigue with 100% of their self-estimated 10-RM. Successful determination of 10-RM was measured by participants lifting the estimated resistance between 9-11 repetitions. If unsuccessful in an attempt, participant's passively recovered three minutes and resistance was adjusted by 2.3-9.1 kg based on participant's perception of the needed adjustment until fatigue occurred at 9-11 repetitions during a set.

The same sequence of exercises was incorporated in the baseline and all treatment sessions. All participants completed 10 different exercises. Resistance exercises included: flat barbell bench press (BP), seated dumbbell military press (MP), barbell dead lift (DL), machine leg press (LP), knee extension (KE), machine triceps extension (TE), dumbbell side raises (SR), machine chest fly (CF), and seated machine hip abduction/adduction (HipAB/AD). Sets for BP, MP, DL, and LP were considered core/multi-joint lifts and were completed first in keeping with the NSCA guidelines (16). BP and DL were completed in a counter-balanced order between participants, but kept constant within individuals. Single-joint/secondary exercises were conducted in an order that allowed the greatest rest time between lifts incorporating the same muscle groups (i.e. UB and LB exercises were alternated). The exercises were chosen to include single-joint movements (SR, TE, HipAB, HipAD, KE, CF), and multi-joint movements (BP, LP, MP, DL). Participants were given 90 seconds of recovery between sets and 2 minutes recovery between different exercises. The second set for all exercises was completed to volitional failure at the individualized 10-RM resistance with repetitions completed recorded as the dependent measure. The first set was implemented to produce a standardized amount of fatigue and was prescribed at 85% of the 10-RM resistances for 8 repetitions. This approach reduced the variability in total repetitions between bouts (outside of the fatiguing second set that was completed to failure). After completing the baseline session, participants returned at 24 and 48 h to complete the same testing protocol. Participants that completed their third session 24 h after their baseline session returned for their final (fourth) session 48 h after their 24 h session and vice versa.

Participants estimated their perceived level of recovery (PRS) on a scale from 0-10 (0 being least recovered, 10 being fully recovered) (14) after their first set of each exercise, and rating of perceived exertion (RPE) on a scale from 0-10 (0being extremely easy, 10 being extremely hard) following the second set to failure of each exercise (22). Session RPE was recorded 15 minutes after completing the entire workout protocol.

Statistical Analysis

Due to the non-parametric nature of the dependent values assessed during the testing protocol (Δ repetitions from baseline, RPE, PRS) Wilcoxon matched sign-ranked tests were used to analyze all data (SPSS v. 20, Chicago, IL). Data are expressed in box and whisker plots or as percentage of participants recovered excluding session RPE and change in performance for all lifts combined which are expressed as mean ± SD since they are not displayed in a box and whisker plot form. Statistical significance was determined when $p \leq 0.05$.

RESULTS

Lifters were operationally defined as recovered in this study if they were able to complete within 1 repetition of baseline performance during the second set to failure for each exercise. The same criterion was used for comparisons of all lifts combined, MJ, SJ, UB, and LB after averaging the Δ repetitions from baseline for all applicable lifts (i.e. -1 or greater = recovered; -1.1 = not recovered). A significant difference ($p = 0.007$) was found for change in performance when the Δreps for all exercises were averaged together between 24 h (-1.0 ± 1.4 repetitions) and 48 h (0.4 ± 1.2 repetitions) with 50% of participants at 24 h and 80% at 48 h classified as recovered. Significant differences ($p \leq 0.05$) were observed for all lift type categories between 24 and 48 h, but the only difference ($p = 0.037$) detected between performance of different lift types at the same time point was between MJ and SJ at 24 h (Figure 1).

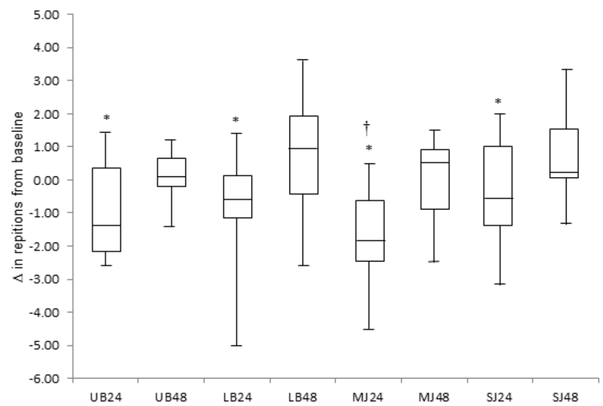

Figure 1. Box and whisker plot comparisons of cumulative means for Δ in repetitions from baseline for upper body (UB), lower body (LB), multi-joint (MJ), and single-joint (SJ) exercises at 24 and 48 h (n = 10; middle line = median; top and bottom boxes represent 2nd and 3rd quartiles; error bars represent min and max scores). * = Significant difference ($p < 0.05$) between 24 and 48 h within lift type category. † = Significant difference ($p = 0.037$) between MJ and SJ at 24 h.

However MJ and SJ at 48 h approached significance (Figure 1; $p = 0.07$). Tables 2 and 3 display the percentages of participants classified as recovered from MJ, SJ, UB, and LB and for each individual exercise at 24 and 48 h respectively. Collectively, these two tables and figure reveal that as expected 48 h of recovery offered marked improvement in performance, and that while replication of MJ lifts suffers more greatly at 24 h than SJ lifts, most MJ and SJ exercises can be replicated at 48 h for the majority of young male recreational weightlifters. The exception to the trend however appears to occur for MJ barbell lifts with BP and DL

Table 2. Percentages of participants recovered[A] from barbell bench press (BP), dead lift (DL), military dumbbell press (MP), leg press (LP), leg extension (LE), machine chest fly (CF), tricep extension (TE), dumbbell side raises (SR), hip adduction (HipAD), and hip abduction (HipAB) exercises at 24 and 48 h (n = 10).

	BP	**DL**	**MP**	**LP**	**LE**	**CF**	**TriEX**	**SR**	**HipAD**	**HipAB**
24 h	60%	50%	60%	60%	60%	60%	70%	50%	80%	80%
48 h	70%	60%	90%	80%	90%	90%	100%	90%	80%	80%

[A] = Lifters were considered recovered if Δ in reps from baseline was ≤ 1 repetition of their baseline session repetition max.

being the only lifts in which 80% or more of lifters were not recovered with 10% fewer participants being recovered for BP versus MP and DL versus LP at 48 h respectively (Table 2).

RPE and PRS estimations for all participants between UB, LB, SJ, and MJ at 24 and 48 h recovery are displayed in Figures 2 and 3. No differences were observed within lift category type between 24 and 48 h for RPE, but lifters reported feeling more recovered ($p \leq 0.05$) based on PRS for all lift category types excluding UB between 24 and 48 h. Increased RPE ($p = 0.021$) and lower PRS ($p = 0.018$) for SJ versus MJ were both reported at 24 h. Session RPE ratings (24 h = 7.7 ± 1.5; 48 h = 7.5 ± 1.9) did not differ ($p=0.58$) between time points.

DISCUSSION

To our knowledge this is the first study that has quantified lifting recovery based on lift type category (LTC). Muscle recovery patterns were examined between SJ versus MJ, and UB versus LB exercise. The results of this study will be compared primarily to two key foundational studies that have attempted to quantify resistance training recovery time based on total changes in repetitions in protocols incorporating both MJ, SJ, UB and LB lifts (8, 15). A description of methodological differences between these investigations and the current study is imperative before comparison of results can be assessed, and Table 1 details the protocols of each study.

The first major difference between studies not represented in Table 1 is the criterion definition for recovery. McLester et al. (15) and Jones et al. (8) required full replication of baseline repetitions, while the current study based recovery on a less conservative criterion of being able to complete ≤ 1 repetition versus the baseline trial performance. Our rationale for requiring completion within only 1 repetition was primarily based on considerations for the minor inherent intertrial variability that exists when lifters are asked to replicate a lifting protocol. In a practical sense, completing an extra day of lifting in a week with 1 less repetition than the previous bouts efforts would plausibly represent a transient state of overreaching and with appropriate periodization would plausibly lead to greater long term gains than lifting fewer sessions during the training week.

Much consideration was also given concerning the overall fatiguing effect of the lifting protocol in the current study. Both previous studies (8, 15) incorporated a design in which 3 versus 2 sets were used for each lift, all sets were completed to fatigue with the dependent variable being recovery evaluated on the first set of each exercise, and McLester et al. (15) allowed a much shorter recovery period between sets (Table 1). We opted not to lift to fatigue on every set because of the potential variability in preceding repetitions to influence the final set to fatigue, and because many lifters do not lift to failure every set. The current study incorporated more exercises and fewer sets so more comparisons could be made between LTC. Because of this consideration all upper body lifts chosen focused on extensor muscles (chest, triceps, and deltoids) to hopefully result in more local fatigue since each first set was less fatiguing than the previous 2 investigations that both used upper body pushing and pulling lifts. These factors likely explain the reason why some participants in the current study were able to replicate some lifts during the 24 h trial. Nonetheless, based on quantitative session RPE results from investigators, the protocol was considerably taxing for participants.

NSCA guideline's (19) suggest at least 48 h is needed for muscles to recover, and not surprisingly significant performance differences were found for all LTC between 24 h versus 48 h. All LTC exhibited negative median repetition values at 24 h, but returned to baseline or were slightly positive at 48 h (Figure 1). Evaluating cumulative repetition totals, Jones et al. (8) found 8 of 10 participants were able to replicate the numbers of repetitions completed for 3 sets of 6 exercises at 48 h, and 7 of the 10 same participants repeated their performance after a 3 week washout period. McLester et al. (15) found only 40% of participants were able to replicate the same number of repetitions completed during the first of 3 sets of 8 exercises at 48 h and 0% replication for the 24 h recovery trial. Recovery using our definition (within 1 repetition of baseline) revealed 50 and 80% of participants were recovered at 24 and 48 h respectively when performances for all lifts were combined. However using the McLester et al. (15) and Jones et al. (8) standard for recovery (matching or exceeding baseline) dropped the percentage of participants recovered to 30% (24 h) and 60% (48 h). When examining each of the 10 exercises individually 60+% of participants at 48 h were able to complete within 1 repetition of their baseline performance. If the stricter criteria of complete replication (8, 15) were used in the current study LP, MP, and TE would have each been dropped by 30%, as 3 participants in each lifted completed only 1 less repetition from baseline, further highlighting the impact subtle differences (1 repetition) in definitions can make when interpreting data. It is plausible the lower recovery levels in McLester et al. (15) were due to the shorter recovery time between sets (30-60 s) which was half of what was provided in Jones et al. (8) and the current study (2 min). Simply increasing time between sets may be a strategy that could be incorporated to decrease the amount of days rest needed between lifting sessions. Although our data does not support lifting on consecutive days, increasing time between sets could possibly be beneficial for individuals who require more than 48 h to recover allowing more total lifting sessions to be completed within the same overall time frame.

Table 3. Percentages of participants classified as recovered[A] from multi-joint (MJ), single-joint (SJ), upper body (UB), and lower body (LB) exercises at 24 and 48 h when Δ in reps from baseline was averaged based on exercise type. (n = 10).

	MJ24	MJ48	SJ24	SJ48	UB24	UB48	LB24	LB48
Recovered	30%	70%	50%	80%	40%	80%	60%	80%

[A] = Lifters were considered recovered if the mean Δ in reps from baseline was ≤ 1 repetition of their baseline session repetition max.

The next two important performance trends that our data reveals are (1) lifters recover more effectively from SJ versus MJ at 24 h but even though recovery patterns learn toward similar results at 48 h, MJ exercises still appear to be a little more stunted than SJ exercises and (2) there appears to be no basis to support UB exercise recovery occurs more quickly than LB (16) under the current paradigm. In regards to the first finding, Table 3 shows 7 of 10 participants were not able to perform within ≤ 1 repetition from the baseline trial for all MJ lifts at 24 h rest versus 5 for all SJ exercise at 24 h.

This tendency is further exemplified when looking at the differences in medians when comparing SJ versus MJ at 24 h. While the median change in repetitions is more similar at 48 h, the distribution of scores for MJ at 48 h trended downward towards poorer performance versus upwards for SJ (Figure 1). An additional consideration revealed by the data is that all MJ exercises are not equal in regards to time between bout recovery needs. Heavy barbell exercises are a clear exception to the rule in terms of recovery as even MJ free weight exercise with lighter resistance (e.g. MP) and machine MJ exercises (LP) recovered at a faster trend when compared to heavy barbell exercises.

The NSCA (16) suggests UB musculature recovers more quickly than LB exercises. However, no differences in performance were noted between the LTC at the same time points when using Wilcoxon signed rank tests (Figure 1). Table 3 also shows that the same percentages of lifters were recovered at 48 hours rest for UB vs. LB exercises and 2 more participants were considered recovered from combined LB than UB exercises at 24 h. The hypothesis that blood flow to the legs from daily activities improves recovery time in LB versus UB lifts was not supported under the current paradigm. However, because two of the ten participants seemed to recover faster from LB lifts vs UB lifts at 24 h, further research should be conducted to examine this variable. It is plausible that future studies might indicate blood flow to the legs from daily activities improves recovery time in LB lifts vs UB lifts.

The efficacy of perceptual measures (RPE and PRS) were also observed as both have been promoted as tools to encourage optimal strength and conditioning programing by determining whether athletes are adequately recovered. Perceptual measures efficacy in resistance training paradigms have received relatively less consideration than for intermittent high intensity sport or endurance type exercise. For example, Impellizzeri et al. (7) concluded that session-RPE is a good indicator of global internal load of soccer training and high intensity interval training (HIIT). Similar finding were concluded by Wallace et al. (21) who found session RPE provided a practical training load intensity in 12 highly conditioned swimmers. However, few studies have implemented perceptual measures into resistance training protocols. When lifting to failure, post-lift RPE has been evidenced to not differ even when participants have completed fewer repetitions concurrent with caffeine ingestion (3) or when lifting occurs following dehydration of 3% body mass (12). Although more repetitions were completed for all LTC between 48 versus 24 h, and general trends of lower RPE were observed at 48h, particularly for MJ vs. SJ, no statistical differences were exhibited for RPE. It is also worth noting that at least one participant reported maximal average RPE response that approached 10 for every LTC and time point, but at least one participant also averaged below 6 for all 48 h LTC while no lifter responded with an average RPE less than 7.5 for each LTC at 24 h (Figure 2).

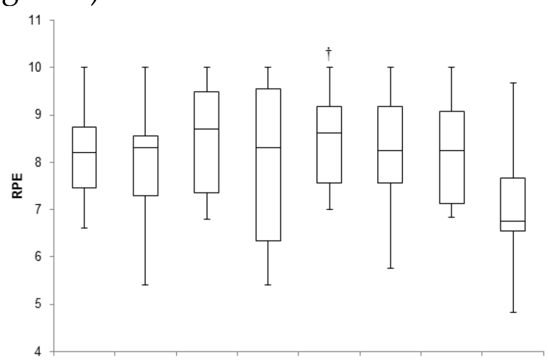

Figure 2. Box and whisker plot comparisons of cumulative means for rate of perceived exertion (RPE) ratings for upper body (UB), lower body (LB), multi-joint (MJ), and single-joint (SJ) at 24 and 48 h (n=10; middle line = median; top and bottom boxes represent 2nd and 3rd quartiles; error bars represent min and max scores). † = Significant difference ($p = 0.021$) between MJ and SJ at 24 h.

Unlike RPE which is typically collected during or after activity, the PRS scale was developed to predict recovery prior to a pending workout (14). Briefly, prior to exercise, participants use a numerical scale with verbal descriptors to assign a value (higher number = more recovered) regarding feelings of recovery. Laurent et al. (14) developed the scale and initially showed that using the PRS scale participants were able to accurately predict performance with a high degree of accuracy (80% of trials). In the current study PRS estimations differed within LTC between 24 and 48 h, and the only difference between LTC within time period occurred between MJ and SJ at 24 h (Figure 3).

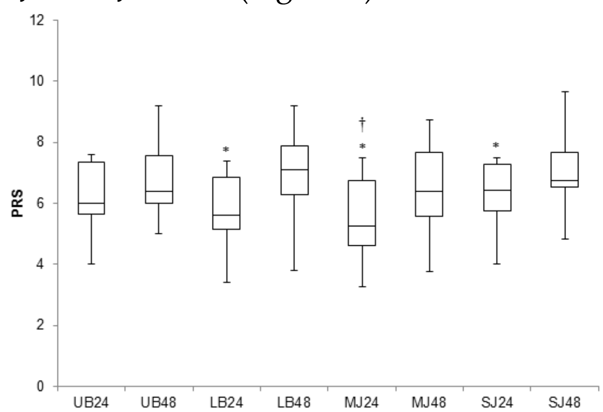

Figure 3. Box and whisker plot comparisons of cumulative means for perceived recovery scale (PRS) ratings for upper body (UB), lower body (LB), multi-joint (MJ), and single-joint (SJ) at 24 and 48 h (n=10; middle line = median; top and bottom boxes represent 2nd and 3rd quartiles; error bars represent min and max scores). * = Significant difference ($p < 0.05$) between 24 and 48 h. † = Significant difference ($p = 0.018$) between MJ and SJ at 24 h.

Comparing subjective estimations with actual performance results supports the utility of using the PRS after a warm up to determine if an extra day of recovery may be needed. The validity of the PRS is further strengthened when examining changes in performance of individual lifts.

The DL exercise experienced the lowest percentage of participants returning to baseline performance and concurrently received the lowest mean PRS estimations of any lift at 24 h (4.7 ± 2.0) and 48 h (6.3 ± 1.8) at 48 h recovery. The highest PRS values (reflecting feelings of well-recovered) were estimated for Hip AB and HipAD which mirrored highest lift replication levels. When lifting to failure RPE appears to be less useful than PRS, but measuring RPE after a lighter warm-up set versus after a final set to failure may increase the utility of using RPE in the strength training paradigm. Furthermore, if a participant completes a warm up set and reports a low RPE rating, this should indicate high performance on the subsequent set. However, the PRS scale seemed to be a greater predictor of performance when compared to the RPE scale (Figures 2 &3).

Coaches of high school and collegiate athletes often are limited to weekday strength and conditioning sessions only, particularly during season. Jones et al. (8) provide evidence that an acute assessment period in which athletes are asked to replicate lifting routines with different between bout recovery period lengths (e.g. 24, 48, 72 h) can be used to reliably identify how many days are required for individuals to recover. With a consideration that quality remains the same, the more sessions that can be completed within this time frame should result in greater long term strength gains. The present study suggests that the majority of recreational weightlifters can replicate within 1 repetition of baseline work within 48 h for lifting protocols incorporating 2 sets of repetitions for 10 exercises. However, free weight, multi-joint exercises, and possibly lower body lifts are less likely to be recovered than single-joint or machine based exercises. Identifying lifters who recover “slowly” or “quickly” could allow program design to incorporate the minimal amount of recovery time needed and offer adjustments such as incorporating exercises that require less recovery time for individuals who recover more slowly. Additionally, the utility of PRS estimations corresponded well with changes in performance and may be beneficial in making on the fly decisions concerning whether an extra period of recovery is needed before a following through with an entire low quality lifting session.

Certain limitations should be considered when interpreting current results. The primary concerns involve the goal and proficiency level of the participants. Only recreational lifters participated in this study and both upper body pushing movements and lower body lifts were incorporated in the same lifting session. The protocol is unlikely to resemble a lifting regiment for a body builder where more focus would likely be placed on distinct muscle groups and include greater volume. Power sport athletes would also likely include Olympic style lifts, and depending on periodization phase include lifts at a higher % of 1-RM. Future studies examining recovery during body building or power sport type training at 48 h are warranted as are additional investigations regarding the utility of perceptual measures (i.e. PRS) for assessing recovery status.

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