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Effectiveness of Whey Protein Hydrolysate and Milk-Based Formulated Drinks on Recovery of Strength and Power Following Acute Resistance Exercise

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Intensive resistance exercise can result in exercise-induced-muscle-damage, which commonly leads to reductions in acute muscle function. Post-exercise ingestion of carbohydrate-protein mixtures intends to attenuate these effects. This study aimed to compare the effectiveness of whey protein hydrolysate and milk-based formulated drinks on recovery of muscle function following resistance exercise. Thirty resistance-trained males were randomly assigned to either whey hydrolysate and dextrose drink (WH), milk-based drink (MB) or flavored-dextrose (CHO), and performed baseline assessments of perceived-muscle-soreness, the countermovement jump, the seated-medicine-ball throw and isokinetic assessment of the knee extensors and flexors maximal strength. Subsequently, participants performed resistance exercise consisting of various multi-joint barbell exercises. Following resistance exercise participants then consumed either WH (533 Kcal, 32.6 g Protein, 98.3 g Carbohydrate, 1.1 g Fat), MB (532 Kcal, 32.8 g Protein, 98.4 g Carbohydrate, 0.6 g Fat) or CHO (531 Kcal, 0 g Protein, 132.7 g Carbohydrate, 0 g Fat). All assessments were repeated 24 and 48 h post-resistance exercise. Muscle soreness was markedly increased at 24 h and 48 h in all groups ($p < 0.001$). However, for dynamic power measures (countermovement jump, seated-medicine-ball throw), CHO experienced a decrease for the countermovement jump only at 48 h, whereas WH and MB experienced significant decreases across the countermovement jump and the seated-medicine-ball throw ($p < 0.05$). All groups experienced significant decreases in isokinetic-extension torque at both 24 h and 48 h; however, flexion torque was decreased for CHO only at these time points ($p < 0.05$). Consumption of WH or MB did not enhance recovery of dynamic power-producing ability or soreness compared to CHO. Based on within-group effects WH and MB ingestion had seemingly marginal to small positive effects on recovery of isokinetic strength, however, there were no between-group differences for these variables.

***Key words**: strength training, ergogenic aids, muscle function, muscle damage.*

Introduction

Resistance training is considered an integral part of the structured regimen of many athletes (Gee et al., 2011b). However, researchers have shown that acute bouts of intensive resistance exercise result in transient muscle soreness (< 48 h) and decrements in various aspects of athletic muscle function such as jump height, force production, and upper-body power-producing ability (Gee et al., 2011a, 2012, 2016; Hoffman et al., 2010). The magnitude of such decrements in muscular function has commonly been reported as 5-7% below baseline performance values 24-48 h following acute resistance exercise (Gee et al. 2011a, 2012; Raastad and Hallen et al., 2000). Since many elite athletes perform multiple daily training sessions, the efficient recovery of muscle function following resistance training is essential for the maintenance of quality training output (Byrne et al., 2004; Gee et al., 2011b). Nutrient availability following acute resistance exercise bouts, most importantly protein and carbohydrate provision appears to be an important determinant for muscle fibers to be repaired effectively and muscular hypertrophy to occur (Reidy and Rasmussen,

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2016). Indeed, a positive net protein balance following resistance exercise has shown to be dependent upon dietary amino-acid availability (Tipton et al., 1999). In addition carbohydrates are essential to replenish post-exercise glycogen stores, thus influencing the regulation of molecular signalling pathways such as Akt and mTOR which affect cellular growth and adaptation in response to resistance exercise, and contribute to an anabolic hormonal environment by increasing insulin (Børsheim et al., 2004; Creer et al., 2005).

Due to these effects, it is a common practice for athletes to ingest supplemental drinks containing a mixture of protein and carbohydrates following exercise (Pasiakos et al., 2015). Two protein sources that are commonly used in such drinks specifically for their recovery promoting effects are milk protein and whey protein hydrolysate. Research has shown that both whey protein hydrolysate and milk-based drinks are effective at enhancing recovery of muscle function following bouts of resistance training and repeated sprint exercise (Brown et al., 2018; Buckley et al., 2010; Cockburn et al., 2008; Cooke et al., 2010). However, surprisingly no singular research study has compared the recovery eliciting effects of these two drinks following training of any kind. Whey hydrolysate is a pre-digested protein containing mostly dipeptides and tripeptides, which are absorbed more rapidly than free-form amino acids and much more rapidly than intact (non-hydrolysed) proteins (Manninen, 2004). It has been speculated that a combination of whey hydrolysate and high-glycaemic carbohydrates provides the optimal post-exercise recovery drink (Manninen, 2006). Concomitantly nutritional mixtures containing whey protein hydrolysates significantly augment plasma amino-acids concentrations, muscle protein synthesis and insulin response compared to cow's milk or casein protein mixtures (Calbet and MacLean, 2002; Pennings et al., 2011; Tang et al., 2009), with these responses being shown following ingestion at rest and acutely following resistance exercise. These effects may theoretically lead to an increase in the rate of protein synthesis and potentially a more rapid and complete restoration of muscle function following stressful training. Acute and longitudinal supplementation of whey protein hydrolysate has shown greater benefit in comparison to other non-hydrolysed forms of whey protein and carbohydrate-only conditions for recovery of indices of muscle function such as jump height, isometric force, and blood markers of muscle damage (Buckley et al., 2010; Hansen et al., 2014; Lollo et al., 2014).

This study aimed to compare the effectiveness of whey protein hydrolysate and milk-based formulated drinks on recovery of muscle function following acute resistance exercise.

Methods

Participants

In a randomised within and between-group double-blind design, thirty resistance-trained males were recruited from a university population (mean ± standard deviation: age: 25.2 ± 5.5 years, body mass: 79.4 ± 8.4 kg, body height: 1.77 ± 0.45 m). Each participant had at least one year of resistance training experience, and was currently engaged in resistance training. Participants were informed of the experimental procedures and provided written informed consent. The study was approved by the School of Sport and Exercise Science ethics committee at the University of Lincoln in-line with the Declaration of Helsinki for research with human volunteers. Participants were evenly (n = 10) and randomly assigned to one of the three groups: (i) whey hydrolysate-based drink (WH), (ii) milk-based drink (MB), (iii) flavored dextrose / carbohydrate (CHO).

Nutritional supplements

All drink conditions were prepared and provided in black water bottles and were administered to participants by a member of the experimental team who was not involved in data collection of the various assessments, hence the double-blind design. The nutritional content of each drink is shown in Table 1. The WH contained strawberry flavored whey hydrolysate (39 g of Strawberry flavor Hydrolysed Whey Protein Isolate, Bulk Powders, Colchester, Essex, UK) a form of whey protein isolate pre-digested by enzymes for increased speed of absorption and delivery to muscles (Atherton and Smith, 2012), along with 97 g dextrose powder as a source of carbohydrates (Bulk Powders, Colchester, Essex, UK). The MB condition was two pre-mixed bottles of a commercially available low-fat berry flavored milkshake designed to facilitate an athlete's

recovery after exercise (Superberry flavor For Goodness Shakes, My Goodness Ltd., London, UK). This product provided protein in the form of skimmed milk, and simple carbohydrates in the forms of lactose, sucrose, fructose and maltodextrin. For the CHO condition, 133 g dextrose powder (Bulk Powders, Colchester, Essex, UK) was provided with a strawberry-flavored non-calorie sweetener (Strawberry Liquiflav, Bulk Powders, Colchester, Essex, UK). All conditions were matched for calories to eliminate this as a possible cause of effects (Richardson et al., 2012). The volume of all drinks consumed was 900 ml each following mixing the powders with water. Following administration 10 min post exercise, participants consumed their drink within a 10 min period.

Resistance exercise session

The resistance exercise session consisted of a series of multi-joint exercises (Table 2), with a design similar to that used within previous research (Dorrell and Gee, 2016). Each exercise was performed for 4 sets of 8 repetitions at 75% of one-repetition maximum (1-RM), with 2-min rest intervals allocated between each set. Individual loading of exercises was determined from 1-RM assessment, established prior to the experimental protocol. There were no significant differences for 1-RM on any of the featured exercises between groups, confirmed via one-way ANOVA tests ($p > 0.05$). The featured exercises were selected based on their replication of the structural resistance lifts often used as the basis of athletic resistance training programmes (Gee et al., 2011b; Ebben and Blackard, 2001). Upon completion of the session, participants remained seated for 10 min before being administered with their respective supplemental drink.

Procedures

Throughout their involvement, participants maintained their normal daily lifestyle and diet. Participants were asked to abstain from strenuous exercise 48 h before baseline testing and arrive at the laboratory in a hydrated state. Participants were advised to abstain from nutritional supplements for the duration of the study protocol; moreover, diet and activity were self-recorded for each participant during the 24 h prior to baseline testing. Participants were provided with a diet and activity diary and were asked to replicate their diet and activity from the day before baseline testing, the day of baseline testing, the day of the resistance exercise session and from both 24 h and 48 h post resistance exercise testing sessions, respectively. The diet and activity diary served as a replication tool for participants at the specified time points; however, diet and activity patterns were not subsequently explicitly analysed. Participants adherence to replicated dietary and activity patterns was confirmed via self-report at each specified lab visit. Time of day was controlled for participants' assessment sessions (baseline, 24 h and 48 h). Prior to baseline testing all participants attended a protocol familiarisation session where they were habituated to all assessments. During the baseline testing session, body mass and height were measured (710 Mechanical column scale, 213 Portable stadiometer; Seca, Hamburg, Germany). Participants then completed a total of five bodyweight squats and subsequently used the visual analogue scale to transcribe their perceived levels of muscular soreness whilst executing the squats. Each participant then completed a 5-min warm-up on a cycle ergometer at 60 W (60 r·min^{-1}) (Ergomedic 874E, Monark, Sweden), followed by three individual countermovement jumps (CMJ) and seated medicine-ball throws (MBT). Following this participants carried out a further 5-min warm-up on the cycle ergometer prior to isokinetic assessment. Isokinetic assessment included completing five maximal-effort knee flexion and extension actions at 60°/s using the dominant-leg after two warm-up sets, which completed the protocol of assessments. Participants then completed three sessions on three consecutive days, beginning with the resistance exercise session and subsequent ingestion of the experimental supplemental drink, after this two further follow-up testing sessions, identical to baseline testing, were performed at 24 h and 48 h post resistance exercise session, respectively.

Experimental test battery

Rating of perceived soreness (SORENESS)

A 200-mm visual analogue scale, used previously (Howatson et al., 2012) was applied to assess SORENESS. Participants marked their level of subjective pain using a vertical line along the continuum which ranged from "no muscle soreness / pain" (0 mm) to "muscle soreness / pain as bad as it could be" (200 mm).

Countermovement jump (CMJ)

The Just Jump measurement system (Just Jump, Probotics, Huntsville, AL, USA) was used for assessment. Three independent trials of the CMJ were conducted with 30 s rest intervals in-between. The highest jump was recorded for data analysis. Participants positioned themselves in the centre of the jump mat, and placed their hands on the iliac crest and maintained this throughout. The CMJ test began from an erect standing position with both hands on the iliac crest. Participants squatted to their perceived optimal depth and then immediately ascended to jump vertically for maximal height.

Seated medicine-ball throw (MBT)

The MBT was completed using a 3 kg medicine ball. Participants assumed a seated position against a wall, with knees flexed at 90° and feet flat on the floor. Once in the starting position, participants were instructed to throw the ball to achieve the greatest horizontal distance possible, maintaining contact with the wall at all times throughout the movement. Three maximal effort throws were completed by each participant with 30 s rest intervals in between. The throw of the greatest distance was used for further analysis.

Isokinetic peak torque

Peak torque (J) during maximal-effort concentric knee flexion and extension actions was measured on the dominant leg at a velocity of 60°/s. Participants positioned themselves seated on the Humac Isokinetic Dynamometer (Humac, Staughton, MA, USA) for isokinetic assessment of the knee flexors and extensors under concentric conditions and were required to maximally extend and flex their leg over their maximum range of motion (ROM) for five repetitions.

Statistical analysis

Data are presented as mean ± [standard deviation], unless stated otherwise. The participants' number used for analysis was n = 10, with exception of isokinetic measures (n = 9) where a single outlier was present in each group. Participants were identified as outliers via the 'standard deviation method', whereby their mean change score from baseline to post intervention trial (either 24 h or 48 h) exceeded two standard deviations of the group mean change score (Bain and Engelhardt, 1992). Data were analysed using SPSS for Windows, release 22.0 (SPSS, IBM Corporation, Armonk, NY, USA). Assumptions of sphericity were assessed using the Mauchly's test of sphericity. Changes in assessed measures (SORENESS, CMJ, MBT, isokinetic peak torque) across the three trials (baseline, 24 h, 48 h post resistance exercise) were analysed using two-way (group x time) ANOVA. The alpha level for significance was set at $p < 0.05$ for all analyses and the LSD correction was used for pairwise comparisons. In addition, effect size (*ES*) was calculated for any significant within-group changes (from baseline to post intervention trials) corresponding with procedures suggested by Hopkins et al. (2009). In accordance with these procedures, interpretation of observed effect sizes was as follows: trivial < 0.2, small 0.2 - 0.6, moderate 0.6 - 1.2, large 1.2 - 2.0, very large > 2.0 (Hopkins et al., 2009).

Results

Baseline assessment data

There were no significant differences at baseline between groups for any of the assessed performance measures (SORENESS, CMJ, MBT, isokinetic peak torque) ($p > 0.05$).

Perceived muscle soreness

A significant effect existed over time for SORENESS ($F = 59.26$, $p < 0.001$). Values for all groups were significantly increased from baseline at 24 h and 48 h ($p < 0.01$), with effect sizes ranging from 'large to very large' (*ES* = -1.70 to -2.86). However, there were no between-group differences in SORENESS across time ($F = 0.40$, $p = 0.809$). Results of the data analysis can be seen in Table 3.

Countermovement jump

Within-group analysis revealed a significant effect existed over time for countermovement jump height ($F = 16.96$, $p < 0.001$). There was a significant decrease in CMJ height between baseline and 24 h for WH (*ES* = 0.44) and MB (*ES* = 0.64) ($p < 0.05$); while at 48 h there were significant decreases for MB (*ES* = 0.48) and CHO (*ES* = 0.31) in relation to baseline ($p < 0.05$). There were no between-group differences in the CMJ across time ($F = 1.15$, $p = 0.350$).

Seated medicine-ball throw

A significant effect existed over time for MBT distance ($F = 9.069$, $p = 0.002$). In regard to within-group measures, there was a significant decrease in MBT distance between baseline and 24 h for MB (*ES* = 0.74) ($p < 0.001$), and a decrease

between baseline and 48 h for both WH (*ES* = 0.31) and MB (*ES* = 0.83) ($p < 0.05$). However, for CHO there were no significant differences in MBT distance between baseline and both 24h and 48h. There were no between-group differences in MBT across time ($F = 2.64$, $p = 0.079$).

Isokinetic peak torque

A significant main effect for time existed for leg extension peak torque ($F = 18.52$, $p < 0.001$). A significant decrease in extension torque for all groups was present between baseline and both 24 h and 48 h ($p < 0.05$), represented with generally moderate effect sizes (*ES* = 0.50 to 0.92). A significant effect existed over time for leg flexion peak torque ($F = 8.32$, $p = 0.003$). There were significant decreases between baseline and both 24 h (*ES* = 0.43) and 48 h (*ES* = 0.54) for CHO ($p < 0.05$), however, no significant decreases existed in flexion torque for WH or MB ($p > 0.05$). There were no between-group differences across time in extension ($F = 0.72$, $p = 0.584$) or flexion torque ($F = 0.85$, $p = 0.507$).

Table 1

Nutritional content of supplemental drinks

	WH	MB	CHO
Energy (Kcal)	533	532	531
Protein (g)	32.6	32.8	0
Carbohydrate (g)	98.3	98.4	132.7
of which sugars (g)	97.6	96.8	132.7
Fat (g)	1.1	0.6	0

WH: Whey hydrolysate + dextrose (39 g of Strawberry flavor Hydrolysed Whey Protein Isolate, 97 g Dextrose powder, Bulk Powders, Colchester, Essex, UK). MB: Milk-based protein carbohydrate drink, (two bottles of Superberry flavor For Goodness Shakes, My Goodness Ltd., London, UK). CHO: Carbohydrate (133 g Dextrose powder mixed with Strawberry Liquiflav, Bulk Powders, Colchester, Essex, UK).

Table 2

Resistance exercise session and mean [standard deviation] of 1-RM achieved by participants on the exercises featured.

Exercise	Sets x reps	% 1-RM	WH 1-RM (kg)	MB 1-RM (kg)	CHO 1-RM (kg)
Squat	4 x 8	75%	117 [17]	103 [35]	94 [17]
Bench press	4 x 8	75%	84 [14]	83 [19]	76 [17]
Deadlift	4 x 8	75%	140 [29]	138 [21]	129 [23]
Military press	4 x 8	75%	48 [6]	50 [12]	46 [7]
Bench pull	4 x 8	75%	74 [8]	78 [12]	70 [11]

Table 3

Comparison of dependent variables at baseline and post resistance training

	WH (n = 10)			MB (n = 10)			CHO (n = 10)		
Measure	Baseline	24 h	48 h	Baseline	24 h	48 h	Baseline	24 h	48 h
SORENESS (mm)	19 [19]	102* [39]	99* [52]	25 [22]	106* [51]	94* [59]	26 [17]	91* [33]	84* [51]
CMJ (cm)	50.8 [6.2]	48.4* [4.7]	49.2 [5.1]	50.4 [6.3]	46.8* [4.9]	47.2* [7.0]	46.3 [5.2]	44.9 [5.9]	44.5* [6.4]
MBT (m)	5.35 [0.90]	5.26 [0.70]	5.10* [0.71]	5.54 [0.42]	5.21* [0.47]	5.16* [0.50]	5.37 [0.58]	5.37 [0.68]	5.31 [0.63]
Peak Torque Extension (N·m)	189 [33]	159* [33]	168* [27]	195 [23]	179* [20]	177* [16]	193 [39]	173* [37]	173* [41]
Peak Torque Flexion (N·m)	105 [17]	101 [16]	100 [15]	113 [21]	108 [15]	106 [18]	118 [25]	108* [21]	105* [23]

** = Significantly different from baseline trial ($p < 0.05$). Data are shown as mean [standard deviation]. WH: Whey hydrolysate + dextrose. MB: Milk-based protein carbohydrate drink. CHO: Carbohydrate. SORENESS: Rating of perceived soreness. CMJ: Countermovement jump. MBT: Seated medicine-ball throw*

Discussion

This is the first study to compare the effectiveness of both whey hydrolysate and milk-based drinks on recovery of muscle function following acute resistance exercise. Globally, there was no apparent difference in recovery response between WH, MB and CHO conditions following intensive resistance exercise. Findings also revealed that neither WH nor MB were more effective at attenuating muscle soreness or dynamic power (measured by jumping and throwing ability) when compared to a CHO (carbohydrate-only) condition. Isokinetic leg flexion peak torque was maintained following the two protein-carbohydrate conditions, whereas these measures were significantly decreased for hose consuming a carbohydrate-only solution.

There were seemingly only marginal to small effects on the attenuation of the decrease in flexion peak torque at both 24 h and 48 h post resistance exercise for WH and MB conditions. Previous authors have reported larger effects on recovery of knee flexion torque following ingestion of protein-carbohydrate solutions in comparison to carbohydrate only conditions. Cockburn et al. (2008) recorded enhanced recovery of knee flexion torque 48 h following eccentric resistance exercise after consumption of a milk-based protein-carbohydrate drink compared to ingestion of a carbohydrate-only drink condition. In addition, Cooke et al. (2010) reported a maintenance of

isokinetic flexion strength following strenuous eccentric resistance with a daily supplementation regime of whey hydrolysate. Theoretically, the synergistic intake of protein and carbohydrate immediately post-exercise compared to carbohydrates alone leads to increased amino-acid availability, enhanced muscle protein synthesis and a decreased rate of protein breakdown (Bird et al., 2006; Tang et al., 2009). Slower rates of muscle protein synthesis at rest and post-resistance training have been found following consumption of milk-based proteins (cow's milk and casein) when compared to whey protein hydrolysate (Calbet and MacLean, 2002; Pennings et al., 2011; Tang et al., 2009). However, this seemingly had no meaningful impact on recovery of muscular strength and power between the two protein conditions.

Muscle soreness was not significantly attenuated at any time point across all groups. In a review, Pasiakos et al. (2015) summarised that in spite of the observed acute benefits of protein supplementation on post-exercise muscle anabolism, there is no apparent relationship between ratings of muscle soreness when protein supplements are consumed after a bout of resistance exercise. This finding is in accordance with observations following eccentric exercise of the knee extensors and flexors. Cockburn et al. (2008) discovered no significant attenuation of muscle soreness when comparing a milk-based recovery drink to carbohydrate condition and Buckley et al. (2010) found no difference in soreness response between whey hydrolysate and control conditions. In addition, Brown et al. (2018) reported significant post exercise soreness levels, peaking at 48 h, following strenuous repeated sprint exercise for both whey hydrolysate and carbohydrate-only groups, but with no group differences in response. In contrast to the current study, the protein containing drink groups as used by Cockburn et al. (2008), Buckley et al. (2010) and Brown et al. (2018) had significant between-group effects on the recovery of force production without concomitant effects on perceived soreness.

There appeared to be no additional benefit of protein consumption on recovery of measures of dynamic power compared to carbohydrate-only ingestion. The WH and MB groups experienced significant decreases across CMJ and MBT, however, CHO experienced a within-group decrease for only CMJ at 48 h. The results are in contrast to those of previous research that has demonstrated that whey hydrolysate in isolation or a combination of high glycaemic-index carbohydrates and protein provides attenuation of power and whole-body athletic performance following exercise-induced muscle damage. Brown et al. (2018) found post exercise whey hydrolysate supplementation to significantly attenuate decreases in jump performance compared to an isocalorific carbohydrate condition following muscle damaging repeated sprint exercise. Hansen et al. (2015) demonstrated improved 4 km run performance and increased ability to deal with strenuous training within top-class orienteering runners using a combination of whey hydrolysate and carbohydrate compared to an isocalorific carbohydrate-only condition. In addition, Hall et al. (2013) showed enhanced time-trial performance in cyclists, following ingestion of casein and with carbohydrate during a previous long duration training bout compared to ingestion of a carbohydrate-only condition. It is theorised that the provision of fast digesting protein sources, such as whey hydrolysate, following resistance exercise results in increased delivery of amino acids to muscle (Manninen, 2006; Tang et al, 2009). Subsequently, this increases protein synthesis and decreases protein breakdown resulting in a positive protein balance (Tipton et al., 1999). The resulting positive protein balance has been attributed to aid in the recovery of contractile tissue, allowing higher force production in subsequent exercise (Cooke et al., 2010). This notion is supported by research which has reported reduced concentrations of plasma enzymes, associated with muscle damage, such as Creatine kinase and Lactate dehydrogenase, post resistance exercise following ingestion of whey hydrolysate compared to isocalorific carbohydrate ingestion (Brown et al., 2018; Cooke et al., 2010). However, in contrast to the current study, within the aforementioned research, multiple boluses of whey hydrolysate were provided at regular time-points following resistance training in addition to participants' regular dietary intake (Brown et al., 2018; Cooke et al., 2010). Therefore, to record significant / meaningful effects on acute recovery compared to isocalorific carbohydrate conditions, supplemental protein dosing may have to be provided on a more frequent and extended period

of time post-resistance training.

The recovery eliciting effects of carbohydrate-only solutions have been documented to provide significant increases in glycogen replenishment and muscle function recovery (Børsheim et al., 2004; Ivy, 2004; Richardson et al., 2012). Carbohydrate intake post-exercise has been shown to increase muscle amino-acid uptake and synthesis, whilst reducing protein degradation, which resultantly promotes muscle anabolism (Børsheim et al., 2004; Ivy, 2004). Muscle glycogen synthesis is considerably increased post-exercise due to a faster rate of glucose uptake as a result of increased sensitivity of musculature to insulin (Børsheim et al., 2004). It is possible that the significantly higher amount of carbohydrate found in the nutritional supplement consumed by the CHO group compared to both experimental groups (133 g vs. 98 g) was responsible for the observed similarities in recovery of various variables of post-training muscle function between conditions. Although, the participants in the current study were required to replicate their existing self-reported diet on all days of the experimental protocol, it should be acknowledged that a limitation of the current study was the lack of provision of a prescribed controlled diet across all participants. This would have given greater control regarding the consumption of habitual dietary carbohydrate across participants, and provided greater awareness regarding the influence of carbohydrate consumption on recovery of muscle function.

The isocalorific conditions featured in the current study may explain differences in findings in comparison to previous authors. Cockburn et al. (2008) recorded enhanced recovery of isokinetic knee flexion peak torque 48 h post exercise-induced muscle damage following ingestion of protein-carbohydrate milk-based drink in comparison to carbohydrate-only condition. However, the authors featured the carbohydrate drink group was not matched for calories with the protein-carbohydrate drink group. Although matched for volume, the purposeful use of non-isocalorific drinks may have contributed to the group differences in observed results found as the protein-carbohydrate drink (707 Kcal) contained a substantially higher number of calories than the featured carbohydrate-only drink (280 Kcal).

In summary, consumption of WH or MB did not enhance recovery of dynamic power producing ability or perceived muscle soreness compared to an isocalorific carbohydrate-only condition. Ingestion of WH and MB had seemingly marginal to small effects on recovery of isokinetic flexion torque. However, these effects were not as pronounced as described within previous related literature, which has demonstrated between-group differences for recovery of muscle function following ingestion of protein-carbohydrate drinks compared to carbohydrate-only conditions.

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