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The effect of a bodybuilding carbohydrate-loading protocol on anthropometry: preliminary findings from a randomised crossover trial

Kai A. Homer , Ivan Jukic , Matt R. Cross , Eric R. Helms

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Highlights

- Carbohydrate (CHO)-loading protocols are commonly implemented by bodybuilders.
- Four males completed this double-blind randomised crossover trial.
- Participants consumed 9g/kg CHO or placebo drinks following 3 days of 1-2g/kg CHO.
- Changes may not be large enough to exceed measurement error and daily variation.
- Coaches and competitors should test protocols well in advance of competition.

The effect of a bodybuilding carbohydrate-loading protocol on anthropometry: preliminary findings from a randomised crossover trial

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Kai A. Homer[1], Ivan Jukic[2], Matt R. Cross[1], Eric R. Helms[1,3]

[1]Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology. [2]Division of Sport and Exercise Sciences, School of Applied Sciences, Abertay University, Dundee, United Kingdom. [3]Florida Atlantic University, Department of Exercise Science and Health Promotion, Muscle Physiology Laboratory, Boca Raton, FL, United States

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Corresponding author:

Kai A. Homer

Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology.

17 Antares Place, Rosedale, Auckland 0632, New Zealand.

kai.homer@aut.ac.nz

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Data availability statement: The associated datasets, custom R script, and full reliability statistics are made available at the Open Science Framework repository (https://osf.io/76jy9/).

Abstract

To acutely enhance muscle size and definition, carbohydrate (CHO)-loading protocols are commonly implemented by bodybuilders in the week before competition. This study sought to evaluate the effects of a bodybuilding CHO-loading protocol on anthropometry. Four dieting males engaging in resistance training (RT) with very low body fat participated in this randomised crossover trial. Each experimental period consisted of data collection on days one, four, and five corresponding to baseline, post-depletion, and post-loading phases, respectively. During depletion, a standardised RT regimen and diet was followed. This diet was maintained on day 4 with the addition of placebo (PLA) or CHO drinks which contained 9g/kg BM CHO for post-loading data collection on day 5. Body mass (BM), skinfold thickness (SF), and ultrasound muscle thickness (MT) was obtained with descriptive data at both group and individual level calculated. From baseline, BM, SF, and MT mostly decreased in both conditions following depletion. All outcomes then increased from post-depletion following CHO-loading (BM: +0.8%, SF: +1.1%, MT: +2.9%) but not with PLA. Comparing to baseline, post-loading changes were greater with CHO (BM: +0.3%, SF: -2.3%, MT: +2.1%) than PLA (BM: -0.9%, SF: -0.5%, MT: -0.8%). Individual differences in response to each phase were also observed. Group level changes seemingly favour CHO-loading; however, it is difficult to judge these changes practically meaningful as they may not be large enough to exceed measurement error and daily biological fluctuations. Before implementation, coaches and competitors should consider individualising protocols through pre-competition testing and visually assessing changes in physique.

Keywords: peaking, physique sport, sports nutrition; carbohydrate

Introduction

In competition, bodybuilders are subjectively judged and ranked on variables such as muscle size and conditioning (low body fat) [1]. To acutely enhance these variables, athletes typically alter nutritional and training practices in the week before competition, known as peak week (PW) [2]. Carbohydrate (CHO)-loading is a commonly implemented peaking strategy, often involving multiple days of reduced CHO intake, followed by 1-2 days of increased CHO intake [1, 2]. This strategy aims to increase muscle size through muscle glycogen supercompensation and the associated retention of water following diet and training-induced glycogen depletion [1]. While commonly implemented by competitors, there is a lack of experimental evidence regarding the efficacy of these protocols.

In the only relevant experimental trial, no significant differences in limb girths were found following a CHO-loading trial which consisted of three days of depletion and a day of loading [3]; however, many limitations exist within this study. Notably, participants had much higher body fat than competitors during PW and did not diet before the study [1, 3]. These physiological differences imply the rate and capacity for glycogenesis potentially differed to that of competitors during PW [1]. Additionally, the nutritional protocol utilised the same energy intake during depletion and loading, which may have not been sufficient to induce appreciable glycogenesis [4]. Likewise, the resistance training (RT) protocol was likely not representative of the practices of competitors, with very high set volumes completed to or very close to failure, likely inducing substantial muscle damage which is known to negatively affect glycogenesis [4]. Finally, changes in muscle size were determined using surface anthropometry which may not be as sensitive as ultrasound in detecting granular changes [5]. Therefore, the aim of the study was to determine the effects of an ecologically valid bodybuilding CHO-loading protocol and accompanying RT regimen on body mass (BM), skinfold (SF) thickness, and ultrasound-derived muscle thickness (MT).

Materials and methods

Subjects

Four males (ages 26-40) routinely engaging in RT participated in this study. All subjects satisfied the inclusion criteria of ∑8 SF ≤48mm which was the mean+1SD from a previous observational study of natural male bodybuilders during PW [6]. Subjects had no history of using anabolic steroids and were progressively dieting for ≥8 weeks to replicate the physiological conditions of competitors during contest preparation. Descriptive data of the subjects are presented in Table 1. Subjects provided written, informed consent before commencing the study. This study was approved by the Auckland University of Technology Ethics Committee (approval number: 22/208) and was conducted in accordance with the declaration of Helsinki.

Table 1. Individual subject descriptives.

Subject	Age (yrs)	BM (kg)	Height (cm)	Sum of 8 SF (mm)	Competitor
1	30	83.80	183.1	34.5	No
2	26	70.00	182.1	40.5	No
3	40	83.00	184.8	36.5	Yes (Professional)
4	30	66.64	167.5	45	No

Abbreviations: BM = body mass, SF = skinfolds. The BM and Sum of 8 SF values presented here are from each subject's first baseline data collection.

Design

In this double-blind randomised crossover design, subjects visited the laboratory on six different occasions for data collection over three weeks. Each experimental period, separated by a 9-day wash-out, consisted of data collection on days 1, 4, and 5 which corresponded to baseline, post-depletion, and post-loading phases of the protocol, respectively. During depletion, subjects followed a standardised diet (2.2-2.6g/kg protein, 1-2g/kg CHO, 0.5g/kg fat relative to BM and ≤14g/1000kcals fibre) while maintaining their current supplement regimen. Subjects were instructed to consume exclusively foods and fluids typically consumed during PW (see supplementary material), while ensuring consistency in both food selection and quantities to control for fluid and electrolyte intake. This diet was maintained on day 4 with the addition of placebo (PLA) or CHO drinks which contained 9g/kg CHO from maltodextrin for the post-loading data collection on day 5. The amount of CHO used for loading was based on previous recommendations [1, 7] while also reflecting the values seen in previous observational studies of bodybuilders executing similar protocols [8, 9]. Flavour essence was added to both drinks while 1g of guar gum was added to the PLA drinks to match flavour and texture. To ensure blinding, drinks were formulated by a researcher otherwise not involved in the study who randomly allocated participants to the condition. The study was counterbalanced to control for any potential order effects.

For each experimental week, subjects followed a standardised RT regimen consisting of lower body (LB), upper body (UB), LB, and UB exercises on days 0 (i.e., day before baseline data collection), 1, 2, and 3, respectively. The prescribed RT consisted of each subject's habitual exercises and set volumes performed within a repetition range of 10-20 and to 1-2 repetitions in reserve. Further, exercises with heavily loaded eccentrics that place muscle at long lengths were substituted for exercises involving similar musculature at shorter muscle lengths and without heavy eccentric loading. This training regimen was designed to reduce training stress and deplete muscle glycogen while minimising muscle damage, as seemingly practiced by competitors during PW [10]. No RT was prescribed on day 4 as training tapers before competition, as typically implemented to maximise glycogenesis [1, 8]. Outcomes consisted of BM, SF, and ultrasound MT which were obtained at each data collection in the morning following an overnight fast at the same time (±1hr) to account for diurnal variation.

Methodology

Height and BM were obtained using a wall-mounted stadiometer (Harpenden Stadiometer; Holtain Limited, Crosswell, Wales) and a scale (HW-200KGL; A&D, Tokyo, Japan), respectively. SF thickness of the triceps, subscapular, biceps, iliac crest, supraspinale, mid-abdominal, front thigh, and medial calf sites were obtained by a level 1 ISAK accredited anthropometrist in accordance with the ISAK protocol [11] to the nearest 0.5mm using calipers (Slim Guide; Creative Health Products, Ann Arbor, USA). Each site was measured in duplicate, with a third measurement collected where the first two differed >5%. The mean of two measurements or median of three measurements were used to determine the SF at each site, with the sum of the final values calculated for each day. For MT, ultrasound images were scanned using the Lumify L12-4, linear-array 37mm probe (Philips Healthcare, Amsterdam, Netherlands) set on the Musculoskeletal application in the transverse plane. The probe was connected to a Samsung Galaxy Tablet S7 FE (Samsung, Seoul, South Korea) via a wired USB-C connection through the Lumify application (version 4.04) as a display for scanning. The specific location and limb positioning of the measurement sites (anterior upper arm, posterior upper arm, anterior thigh, posterior thigh, and posterior lower leg) as well as the measurement of MT have been described previously [12]. Images of each site were obtained in triplicate, from which mean values were calculated. The means were then summed across all sites for total MT. Intra-rater reliability of SF and MT measurements were obtained by assessing three individuals otherwise not involved in the study on three separate occasions on the same day with ~2 hours between each trial. Reliability statistics of the sum of SF (ICC=0.99, CV=1.97%, SEM=1.62mm) and MT (ICC=0.99, CV=1.22%, SEM=0.35cm) as well as each individual site (SF: ICC=0.99-1, CV=0-4.58%, SEM=0-0.71mm, MT: ICC=0.97-0.99, CV=1.31-4.02%, SEM=0.07-0.28cm) were calculated. All reliability statistics are made available in the supplementary materials.

Statistical Analysis

Data for each outcome are presented as group level means and raw individual values. Descriptive statistics were calculated in Microsoft Excel (version 2401) and in R language and environment for statistical computing (version 4.2.2). The dataset and the R scripts utilised for this study are available at the Open Science Framework repository (https://osf.io/76jy9/).

Table 2. Group level subject results in both carbohydrate and placebo conditions at each data collection.

	CHO			PLA		
Outcomes	Baseline	Post-depletion	Post-loading	Baseline	Post-depletion	Post-loading
BM (kg)	75.9±9.1	75.5±8.7	76.1±8.9	75.4±8.5	75.1±8.6	74.7±8.7
SF (mm)	38.9±4.2	37.6±5.4	38±4.3	38.8±4.3	38.8±5	38.6±6.2
MT (cm)	23.9±2.9	23.7±3.4	24.4±3.3	24.3±3.3	24.1±3.1	24.1±3

Data is presented as mean±SD. Abbreviations: CHO = carbohydrate, PLA = placebo, BM = body mass, SF = skinfolds, MT = muscle thickness

Results

From baseline, BM (CHO: -0.5%; PLA: -0.4%), SF (CHO: -3.3%; PLA: no change), and MT (CHO: -0.8%; PLA: -0.8%) mostly decreased in both conditions following depletion. At post-loading, all outcomes increased in the CHO condition (BM: +0.8%, SF: +1.1%, MT: +2.9%) but not in PLA (BM: -0.5%, SF: -0.5%, MT: no change) from post-depletion. In comparison to baseline, post-loading changes were more pronounced following CHO-loading (BM: +0.3%, SF: -2.3%, MT: +2.1%) in comparison to PLA (BM: -0.9%, SF: -0.5%, MT: -0.8%). All group level data are displayed in Table 2, while individual data are visualised in Figure 1.

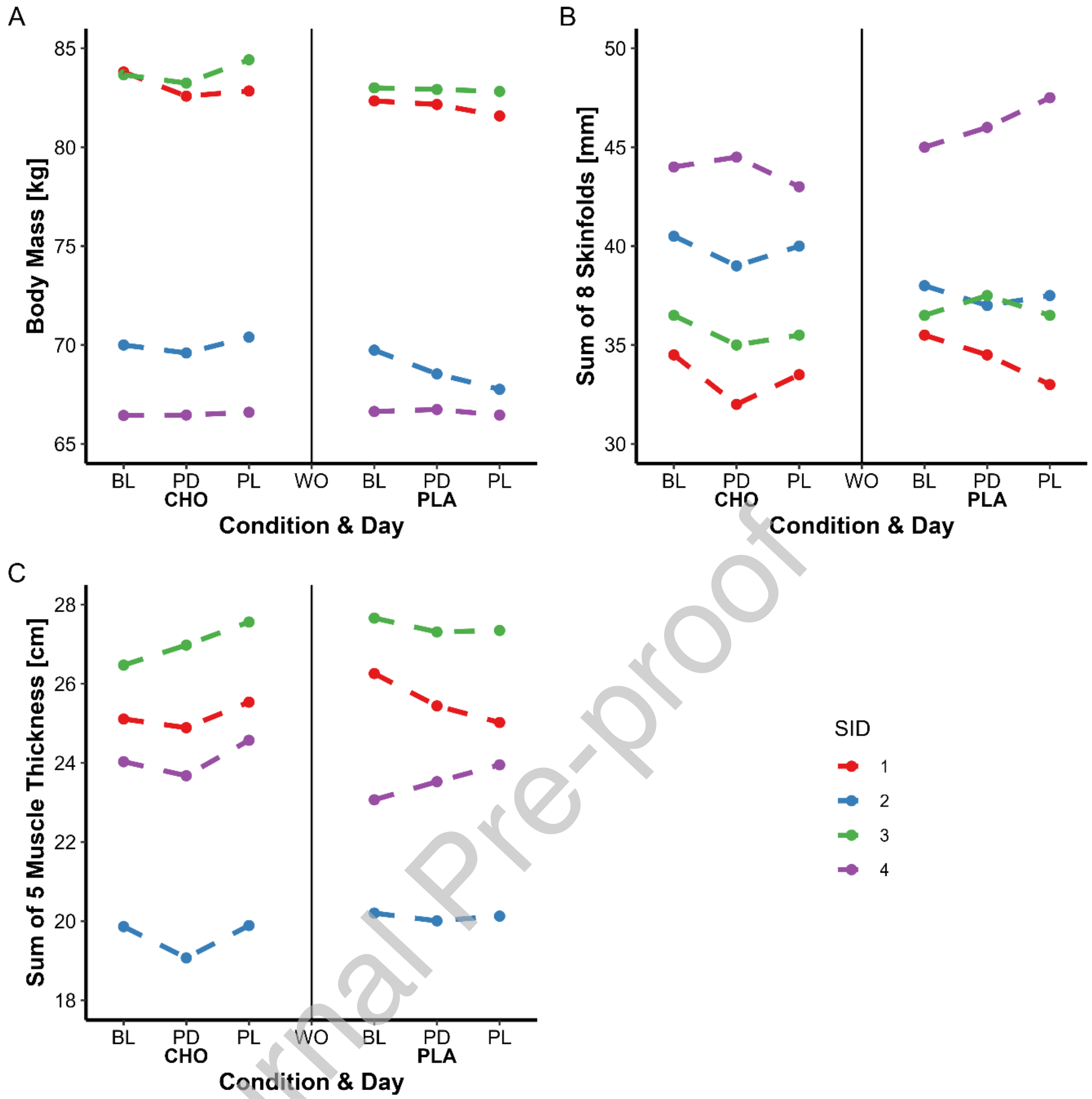

Figure 1. Plots illustrating individual subject results for (A) body mass, (B) Sum of 8 Skinfold Thickness, and (C) Sum of 5 Muscle Thickness on each data collection within both conditions. Abbreviations: CHO = carbohydrate, PLA = placebo, BL = baseline, PD = post-depletion, PL = post-loading, WO = washout, SID = subject identification number.

Discussion

This is the second experimental study to investigate the effects of a bodybuilding CHO-loading protocol on anthropometry. In the present study, the ingestion of 10-11g/kg BM CHO in a day following three days of reduced CHO resulted in increases in BM, MT, and SF at the group level, while changes in the PLA condition were not as pronounced. However, changes in comparison to baseline may not be large enough to exceed measurement error and daily biological variation to be considered meaningful in both conditions. Finally, individual differences in the response to both conditions were observed.

Despite a lack of experimental studies on the topic, CHO-loading protocols have been implemented by physique athletes during PW to acutely enhance muscle size [1]. The only other experimental study on this topic found no differences in limb girths [3] while observational research in bodybuilders reported increased ultrasound MT [8, 13]. The previously reported increase in MT [8, 13] was similar to what was observed in the present study, while considering the discrepancies in protocols and measurement sites between the studies.

While group level changes seemingly favoured CHO-loading in the present study, it is difficult to interpret these differences as large enough to exceed possible measurement error and daily biological fluctuations, and thus may not represent a meaningful change. However, it is also possible that these granular changes across measurement sites amounted to improvements in overall visual appearance which is impactful for performance in competition. Notably, de Moraes et al. [9] observed an improvement in silhouette scores of competitive bodybuilders' physiques evaluated by seven federated judges following a CHO-loading protocol which coincided with an increase in elbow flexor and extensor MT. Nevertheless, due to the limitations of the photo silhouette scale employed (i.e., the discrete nature of the scale and the inability to discern changes in leanness) it is difficult to speculate to what degree overall aesthetics were impacted by the CHO-loading protocol [1]. It is important to consider that visual appearance – the way bodybuilding performance is subjectively judged – was not quantified in our study. Thus, while some improvements in outcomes were noted, the degree to which this affected aesthetics is unknown. Additionally, given the constraints of our small sample size and the preliminary nature of the findings, caution should be applied when generalising for practice. It is therefore crucial that competitors and coaches contemplate the possible downsides of implementing such protocols (e.g., loading with too much CHO and obscuring muscle definition [1]) with the potentially minor aesthetic improvements.

Practical Applications

Given the uncertainty regarding whether the changes in anthropometry in the present study led to meaningful visual changes in appearance, it may not be advisable for newer competitors to implement such protocols due to the possibility for negative effects. Rather, it may be a viable strategy for experienced, high-level competitors to maximise performance. If implementing such strategies, coaches and competitors should test protocols before competition and visually assess changes in physique to individualise and optimise peaking strategies.

Conclusions

This is the second experimental design to examine the effects of a bodybuilding CHO-loading protocol on anthropometry but the first to implement an ecologically valid design and utilise MT measurements. The CHO-loading protocol resulted in increases in MT and BM as well as decreases in SF from baseline; however, these differences may not be large enough to be considered meaningful. Given the preliminary nature of our findings, coaches and competitors should opt to individualise and refine protocols by testing them before competition and visually assessing changes in physique.

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Declaration of interests

☐The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Kai Alexander Homer reports financial support was provided by Renaissance Periodization, LLC. Co-author is a writer and coach in the physique sport and fitness industry - ERH If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.