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DOI:

[10.1139/apnm-2014-0358](https://doi.org/10.1139/apnm-2014-0358)

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Citation for published version (APA):

Rontoyanni, V. G., Werner, K., Sanders, T., & Hall, W. (2015). Differential acute effects of carbohydrate- and protein-rich drinks compared with water on cardiac output during rest and exercise in healthy young men. *Applied physiology, nutrition, and metabolism = Physiologie appliquée, nutrition et métabolisme*, 40(8), 803-810. <https://doi.org/10.1139/apnm-2014-0358>

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Title: **Differential acute effects of carbohydrate and protein rich drinks compared to water on cardiac output during rest and exercise in healthy young men.**

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Short running head: Protein vs. carbohydrate and cardiovascular hemodynamics

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Type of paper: Article

17 **ABSTRACT**

18 The acute effects of drinks rich in protein *vs.* carbohydrate on cardiovascular hemodynamics and
19 reactivity are uncertain. A randomized crossover design was used to compare 400 mL isoenergetic
20 (1.1 MJ) drinks containing whey protein (44 g, PRO) or carbohydrate (57 g, CHO) *vs.* 400 mL
21 water in 14 healthy men. The primary and secondary outcomes were changes in cardiac output,
22 blood pressure, systemic vascular resistance (SVR) and digital volume pulse measured prior to and
23 30 min following consumption at rest, during 12 min of multi-stage bicycle ergometry, and 15 min
24 post-exercise. The mean change (95% CI) in resting cardiac output at 30 min was greater for CHO
25 than for PRO or water: 0.7 (0.4, 1.0), 0.1 (-0.2, 0.40) and 0.0 (-0.3, 0.3) L/min ($P < 0.001$)
26 respectively; the higher cardiac output following CHO was accompanied by an increase in stroke
27 volume and a lower SVR. The mean increments (95% CI) in cardiac output during exercise were
28 CHO 4.7 (4.4, 5.0), PRO 4.9 (4.6, 5.2) and water 4.6 (4.3, 4.9) L/min with the difference between
29 PRO *vs.* water being significant ($P < 0.025$). There were no other statistically significant
30 differences. In summary, a CHO-rich drink increased cardiac output and lowered SVR in the resting
31 state compared to a PRO-rich drink or water but the effect size of changes in these variables did not
32 differ during or after exercise between CHO and PRO. Neither protein nor carbohydrate affected
33 blood pressure reactivity to exercise.

34

35 **KEY WORDS:** Protein, Carbohydrate, Blood pressure, Cardiac output, Cardiovascular reactivity,
36 Exercise

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41 INTRODUCTION

42 Food ingestion leads to significant hemodynamic responses, depending on the meal size and
43 composition. Postprandial hyperemia in the splanchnic area sustained for around 2 - 4 h serves for
44 digestion and absorption and is mainly met by a considerable increase in cardiac output (Waller et
45 al. 1991; Sidery et al. 1994; Hoost et al. 1996). Amino acids from protein hydrolysis enter the portal
46 vein and pass via the liver to the circulation within 15 - 30 min after protein intake (Boirie et al.
47 1997; Hall et al. 2003). Thirty minutes after protein intake, amino acid concentrations in blood are
48 significantly increased, with time and magnitude of the peak concentration differing between
49 different amino acids, occurring on average at 60 min or later and remaining increased for > 2 h
50 (Brundin et al. 1994; Boirie et al. 1997). Maximal values in superior mesenteric artery blood flow
51 were shown to occur at 15 min following intake of carbohydrate and at 45 min following protein,
52 being of similar magnitude (Qamar et al. 1988).

53
54 Long-term exposure to repetitive blood pressure (BP) peaks in response to exercise (Palatini 1998)
55 or other physical or psychological stressors appears to cause various pathophysiologic alterations
56 that may lead to hypertension (Wilson et al. 1990) and CVD (Treiber et al. 2003; Jae et al. 2006).
57 There is evidence showing that even small increases in diastolic BP in response to mild exercise
58 could have the capacity to influence the development of future hypertensive complications (Brett et
59 al. 2000) and that a single meal can influence cardiovascular reactivity (i.e. cardiovascular
60 responses) to stressors. Several previous studies have investigated the acute effects of high fat meals
61 on cardiovascular reactivity to physical and psychological stressors (Jakulj et al. 2007; Rontoyanni
62 et al. 2010; Faulk et al. 2012; Rontoyanni et al. 2012; Sauder et al. 2012) but the effects of high
63 carbohydrate (CHO) or high protein (PRO) meals have yet to be tested. Although several studies
64 have compared a CHO meal with fat, the timing of stressors was selected based on the time course
65 of fat metabolism and peak circulating triglyceride concentration (2-3 h following the meals) and

not when glucose and insulin concentrations peak (Edes et al. 1998; Monteleone et al. 2003; Suzuki et al. 2012). Ingestion of a CHO meal has been claimed to impair endothelial function in the early postprandial state (Suzuki, Watanabe et al. 2012), which may augment vascular resistance and BP responses to stressors. However, this contradicts the established vasodilatory action of insulin on the skeletal muscle vasculature. Earlier studies have postulated that dietary protein, via its effects on blood viscosity and plasma volume, may potentially acutely augment vascular resistance and cardiac output, leading to an elevated BP reactivity to stressors (Dickson et al. 2007; Faulk and Bartholomew 2012). However, these are speculations unsupported by controlled trials. The present study set out to test whether the hemodynamic responses at rest and cardiovascular reactivity to dynamic exercise between moderate-energy dense liquid loads, high in protein or carbohydrate differ. We hypothesised that a drink high in protein that causes rapid increases in blood amino acids, such as whey protein (Boirie et al. 1997), and which raises plasma albumin levels and plasma volume (Okazaki et al. 2009; James et al. 2014), would cause a greater increase in BP reactivity to exercise relative to carbohydrate.

80

81 **MATERIALS AND METHODS**

82 **Participants and screening procedure**

83 Healthy men, aged 18–45 years were recruited from staff and students of King's College
 84 London, UK. Exclusion criteria were: current smoking habit; body mass index ≤ 18.0 or ≥ 30 kg/m²;
 85 BP $\geq 140/90$ mmHg; self-reported history of myocardial infarction, angina, venous thrombosis,
 86 stroke, cancer, presence of gastrointestinal disorder; self-reported weekly alcohol intake of >28
 87 standard units of alcohol (1 unit = 10 ml ethanol); systematic use of any medication. This study was
 88 conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures
 89 involving human subjects were approved by the Research Ethics Committee of King's College

London (REC number: 07/08-57). Participants were given a detailed outline of the study requirements and all provided written informed consent.

Body mass index and BP were confirmed to be within the prescribed limits prior to entry into the study as previously described (Rontoyanni et al. 2010). Waist circumference was measured to the nearest 0.1 cm using a tape measure and percentage body fat was estimated using bioelectrical impedance (Tanita UK Ltd, model: BC-418 MA; Middlesex, UK). In order to ensure participants were suitable to undertake the exercise test, VO_{2max} , an index of cardiorespiratory fitness, was estimated using Astrand-Rhyming cycle ergometer test, a nomogram and age correction factor (Astrand et al. 1954; Astrand 1960), as detailed elsewhere (Rontoyanni et al. 2010).

Experimental design

A randomised, crossover study design was undertaken to test the effects of PRO (44 g protein) or CHO (57 g carbohydrate) drinks, compared to water. Subjects were allocated to one of six treatment sequences in random order (ABC, ACB, BAC, BCA, CAB, CBA - orthogonal Latin square design). Power calculations were based on a change in cardiac output as the primary outcome with 18 participants completing. Each study visit lasted for approximately 2 h and study visits were separated by at least one week. On the day prior to each visit, subjects were asked to avoid alcohol, foods high in fat and protein, caffeine from midday and refrain from vigorous exercise, and they were provided with a standardized low-fat (≤ 10 g fat) and low-protein dinner for their evening meal. They were asked to fast from 22:00 h the previous night, avoiding everything apart from water and to refrain from drinking water and exercise in the morning of the study.

Participants attended a metabolic research unit between 08:00 h and 11:00 h, body mass and height were measured and % body fat was estimated. Following a 20-min quiet, seated rest period, measurements of digital volume pulse (DVP)-stiffness index (SI) and DVP-reflection index (RI) were made in triplicate and of BP, heart rate (HR) and cardiac output in duplicate. Participants then

consumed the test treatment (PRO, CHO or water) within 5 min. Further seated measurements of DVP, BP, HR and cardiac output were repeated 30 min postprandially, followed by a 12-min multi-stage exercise stress test of moderate intensity on a programmable electrically braked cycle ergometer (Ergoselect 100/200, Ergoline GmbH, Bitz, Germany) which has been previously used in similar study protocols (Brett et al. 2000; Brett et al. 2006; Rontoyanni et al. 2010). Workload increased by 25 W in 3-min intervals, starting at 25 W and pedalling frequency was kept constant at 60 rpm. During exercise, further measurements of BP, HR and cardiac output were determined at 3, 6, 9 and 12 min. Immediately post-exercise DVP was obtained and then subjects were allowed to recover seated with further measurements of DVP, BP, HR and cardiac output determined at 15 min post-exercise. An outline of the study protocol is shown in **Fig. 1**. Water ingestion was monitored over the entire study visits period.

Formulation of the test drinks

Three test drinks (400 ml each, chilled to approximately 10 °C) were compared: tap water, a protein enriched drink (PRO) and a carbohydrate enriched drink (CHO). The nutrient content was estimated using food tables (Food Standards Agency 2002) and information provided by the manufacturers (Table 1). The energy, protein, fat and carbohydrate content were 1.1 MJ, 44g, 4g and 9g for PRO and 1.1 MJ, 0.8g, 5g and 57g for CHO, respectively. Protein in the PRO drink was supplied as 40 g whey protein (Body Fortress whey protein strawberry flavor, Holland & Barrett Retail Ltd., Nuneaton, Warwickshire, UK), and 4 g from skimmed milk. Carbohydrate in the CHO drink was supplied as 38g maltodextrin powder (Polycal powder; Nutricia, Trowbridge, Wiltshire, UK) and 19g sucrose as strawberry flavoured 20 g milkshake powder (Nesquik™; Nestlé Ltd., UK). While the drinks were matched for macronutrient content and volume, there were moderate differences between drinks on micronutrients content, which are reported in supplementary Table S1.

140 **Hemodynamic measurements**

141 All measurements were performed with the subject relaxing in an upright seated position in a quiet
 142 and temperature-controlled (23 °C) room. Cardiac output was measured non-invasively using an
 143 inert gas rebreathing device (InnoCor™, Innovision A/S, Odense, Denmark); participants were
 144 familiarized with the rebreathing technique at the beginning of the first study visit prior to any
 145 measurements being taken. A finger arterial BP monitor, the Finometer™ Model-1 (Finapres
 146 Medical Systems BV, Amsterdam ZO, The Netherlands), was used to measure systolic and diastolic
 147 BP, mean arterial pressure (MAP) and HR on a beat-to-beat basis. The Finometer offers continuous
 148 monitoring of the finger arterial pressure waveform and has been shown to provide reliable data
 149 during exercise (Gizdulich et al. 1996). Application of corrective measures, such as waveform
 150 filtering and level correction, a height correction system and arm-cuff return-to-flow calibration
 151 provides accurate BP measurement (Imholz et al. 1998). The finger cuff was applied on the index
 152 finger of the left hand and the arm cuff wrapped around the left arm. Values for BP, MAP and HR
 153 represent means for 30 s epochs for resting and post-exercise measures and means for 5-15 s epochs
 154 during exercise, all recorded immediately before each cardiac output rebreathing manoeuvre to
 155 avoid overestimation due to forced rebreathing. Stroke volume was calculated from cardiac output
 156 divided by HR values. SVR was estimated from MAP divided by cardiac output. DVP
 157 measurements were made in triplicate at each time point using the PulseTrace™ device (Micro
 158 Medical Ltd., Kent, UK) which was attached to the index finger of the right hand. The
 159 PulseTrace™ obtains the DVP by photoplethysmography and is considered to be the sum of direct
 160 and reflected pressure waves. The relative delay in the reflected waves when compared to the direct
 161 wave is strongly related to pulse wave velocity (PWV) in the aorta and large arteries and thus,
 162 provides an index of large artery stiffness (DVP-SI). The amplitude of the reflected component is
 163 used to calculate reflection index (DVP-RI), which depends on vascular tone of peripheral arteries
 164 and thus, is markedly affected by vasoactive drugs (Chowienczyk et al. 1999; Millasseau et al.

2002). Since DVP-SI is strongly influenced by BP changes, its responses to exercise would not be interpreted as a change in large artery stiffness. The hands were kept warm (with the help of a hand electric blanket) during study visits.

Sample size calculation

Initial sample size calculations for 18 participants completing were based on a mean cardiac output of 5.5 L/min with a within-subject SD of differences of 0.47 L/min for measurements on different days, with 14 participants completing the study having 80% power at $P < 0.05$ to detect a 0.5 L/min change in cardiac output allowing for comparisons between three groups.

Statistical analysis

The primary and secondary outcomes were changes in hemodynamics and DVP during exercise (at 3, 6, 9, 12 min) from pre-exercise (30 min postprandial rest) values. Secondary outcomes included changes in hemodynamics and DVP at 30 min rest from baseline (fasting, 0 min) and at 15 min post-exercise from pre-exercise. The main exposure was treatment (3 groups) at different time points. Least square regression models were used to test the effects of treatment and time within subjects. Period was also included as a factor but then omitted from the model if there were no significant effects. Interactions between treatment x time, period x time, period x treatment and period x treatment x time were tested but excluded from the model if they were not statistically significant. Analyses were adjusted for baseline fasting values (for resting condition), and for pre-exercise values (for exercise and post-exercise conditions). Multiple comparisons between treatments were adjusted using a Bonferroni correction. All regression analyses were performed separately for resting, exercise and post-exercise conditions. Differences were considered significant at $P < 0.05$. Values in the results are means (95% CI), unless otherwise specified. Analyses were performed using SPSS statistical software (version 17.0; SPSS, IBM, USA).

190 **RESULTS**

191 Of the 23 subjects who were screened for the study, 14 subjects completed the study and their
 192 details are presented in **Table 2**. Exercise HR and BP (and calculated stroke volume and SVR) data
 193 from one subject were excluded from the analysis due to poor finger arterial pressure waveform
 194 output (due to cold hands). Cardiac output, stroke volume, HR, MAP and SVR responses to the
 195 different treatments at rest, during exercise and post-exercise are illustrated in **Fig. 2 and 3** as
 196 changes from fasting.

198 **Resting postprandial hemodynamics**

199 Statistically significant treatment effects were found for cardiac output ($P < 0.001$), stroke volume
 200 ($P = 0.006$), HR ($P < 0.001$), systolic BP ($P = 0.033$), SVR ($P = 0.002$) and DVP-RI ($P < 0.001$).
 201 As shown in **Table 3**: cardiac output increased and SVR fell following the CHO compared with
 202 PRO and water, and stroke volume increased after the CHO compared with PRO. Heart rate
 203 decreased and DVP-RI increased following water but not following CHO and PRO. Systolic BP
 204 increased after the CHO versus water. There were no further statistically significant differences.

206 **Exercise postprandial hemodynamics**

207 Exercise increased cardiac output, stroke volume, HR, systolic and diastolic BP and MAP and
 208 concomitantly decreased SVR and DVP-RI after treatments (time effect, $P < 0.001$). Results show
 209 statistically significant treatment effects in response to exercise for cardiac output ($P = 0.022$), and
 210 borderline treatment effects on stroke volume ($P = 0.065$) and diastolic BP ($P = 0.050$). As shown
 211 in Table 3: cardiac output reactivity to exercise was greater after the PRO compared to water ($P <$
 212 0.025); the mean increases (95% CI) in cardiac output in response to exercise were 4.7 (4.4, 5.0),
 213 4.9 (4.6, 5.2) 4.6 (95% CI: 4.3, 4.9) L/min after CHO, PRO and water, respectively. Values for all

variables returned close to those pre-exercise 15 min after exercise with no significant differences between treatments (Fig. 2 and 3).

DISCUSSION

The present study compared the acute effects of moderate-energy dense drinks high in rapidly digested carbohydrate or (whey) protein vs. water on cardiovascular hemodynamics at 30 min rest, during exercise and post-exercise. Earlier studies have investigated cardiovascular reactivity to exercise solely following large, solid mixed meals or high fat meals, and of high energy content (2.8 - 6.9 MJ) (Kelbaek et al. 1987; Waaler et al. 1990; Yi et al. 1990; Eriksen et al. 1994; Rontoyanni et al. 2010). Our research adds new information by studying the effects of PRO and CHO test-meals in liquid form with a moderately low total energy content (1.1 MJ) using more robust measures of cardiac output (Agostoni et al. 2005). Large concentrations of amino acids appear in the blood within 20 min following ingestion of whey protein (Boirie et al. 1997). We observed increased cardiac output and reduced SVR at 30 min postprandial rest in response to CHO but not PRO. However, the increase in cardiac output as an effect of CHO was not enhanced compared to PRO during exercise, and BP reactivity to exercise did not differ between PRO and CHO.

Compared with water, the CHO drink produced larger increases in cardiac output and stroke volume, and decreases in SVR; water caused a smaller increase in HR but larger increase in DVP-RI. Similar cumulative effects of the CHO load and exercise on hemodynamics have been reported in earlier studies of solid mixed meals of a greater total energy content (Kelbaek et al. 1987; Waaler et al. 1990; Yi et al. 1990; Eriksen and Waaler 1994; Matheson et al. 2000). Our findings at rest agree with those of earlier studies (Avasthi et al. 1987; Sidery et al. 1991; Waaler et al. 1992; Uijtdehaage et al. 1994; Hoost et al. 1996). As the CHO drink appeared to increase cardiac output via an increase in stroke volume rather than in HR, this would suggest changes either in cardiac

contractility (inotropy), or in filling pressure and end diastolic volume (preload) due to a change in relaxation (a lusitropic effect). The different cardiovascular responses to CHO versus PRO can be attributed to the dilatory effects of insulin and glucose on the skeletal muscle vasculature, and their sympathoexcitatory effects (i.e. on muscle sympathetic nerve activity) (Anderson et al. 1991; Baron 1994; Kearney et al. 1996; Hoffman et al. 1999). However, glucose and insulin were not measured in the present study.

Our data showed that neither carbohydrate nor (whey) protein acute loading augmented pressure wave reflection (DVP-RI) compared to water, which might suggest no redistribution of blood flow from the periphery to the splanchnic area to facilitate the postprandial hyperemic response. The decrease in pressure wave reflection immediately post-exercise as indicated by DVP-RI was in line with the fall in exercise SVR and/or the increase in HR, hence reflecting vasodilation occurring in the exercising vasculature and/or alterations in the timing of the reflected pressure wave (Wilkinson et al. 2000; Wilkinson et al. 2002).

Limitations, conclusions, and future research.

The drinks were matched for macronutrients but there were minor differences in their micronutrient content; the PRO drink contained moderately higher amounts of some minerals and the CHO drink was fortified with vitamins. Fewer participants completed the study than planned but *post hoc* calculations indicate the effect size for the change cardiac output was greater than that for which the study was powered. All 23 participants screened were eligible to participate, but only 14 completed the study (reasons include loss of interest and time constraints). Poor finger arterial pressure waveform output during exercise in 1 participant resulted in exclusion of data derived from these measurements. As this study was conducted in healthy non-obese young men, the findings cannot be generalized to females or individuals with hypertension or altered vascular function. Since an

264 exaggerated BP response to dynamic exercise is an independent predictor of future hypertension
265 (Manolio et al. 1994; Singh et al. 1999) and CVD mortality (Mundal et al. 1994), future research to
266 test cardiovascular reactivity to exercise following meals/drinks of varying macronutrient
267 composition in those with early hypertension or individuals with high normal BP would contribute
268 to current evidence in the prevention of hypertension and to simultaneously monitor changes in
269 insulin and glucose concentrations.

270

271 In conclusion, the findings of the study do not provide support for the hypothesis that a protein rich
272 drink prior to exercise has adverse effect compared to carbohydrate on blood pressure reactivity in
273 response to exercise. However, this study showed that a carbohydrate rich drink acutely increased
274 resting cardiac output and lowered SVR compared with a protein rich drink or water but did not
275 differ from protein or water during exercise.

276 **ACKNOWLEDGEMENTS**

277 This study was supported by the State Scholarships Foundation (I.K.Y.), Greece. The authors
 278 acknowledge financial support from the Department of Health via the National Institute for Health
 279 Research (NIHR) comprehensive Biomedical Research Centre award to Guy's & St Thomas' NHS
 280 Foundation Trust in partnership with King's College London. The authors would like to express
 281 their gratitude to all the participants who allowed this study to be conducted.

282

283 **CONFLICT OF INTEREST**

284 The authors declare that they have no conflict of interest.

285

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Table 1. Macronutrient composition* of the test drinks

Energy and Macronutrients	PRO	CHO
Energy (MJ)	1.06	1.08
Fat (g)	5	5
Carbohydrates (g)	9	57
Sugars (g)	7.5	21
Protein (g)	44	1
L-Glutamic Acid (g)	5.8	-
L-Aspartic Acid (g)	4.6	-
L-Leucine (g)	4.4	-
L-Lysine (g)	3.7	-
L-Threonine (g)	3.2	-
L-Arginine (g)	1.2	-
L-Methionine (g)	0.9	-

***Estimated using food tables (Food Standards Agency 2002) and information provided by the manufacturers.**

Table 2. Details of the male participants

Variables	
Age (y)	25.8 (22.7, 28.8)
BMI (kg/m ²)	22.7 (21.5, 23.9)
Body fat (%)	12.2 (9.8, 14.6)
Waist circumference (cm)	82.5 (78.8, 86.2)
Waist-to-hip ratio	0.83 (0.80, 0.85)
VO _{2max} (mL/kg/min)	46.3 (40.3, 52.3)
Systolic BP (mm Hg)	121.5 (115.7, 127.3)
Diastolic BP (mm Hg)	71.9 (68.7, 75.2)

Values are $\bar{x}$ (95% confidence intervals), $n=14$; VO_{2max}, maximal oxygen uptake;

BP, blood pressure

Table 3. Changes after a high protein drink (PRO), high carbohydrate drink (CHO) or water in hemodynamics and digital volume pulse (DVP) at 30 min rest from fasting (0 h), followed by changes from pre-exercise (30 min) during 12 min exercise.

Drinks		0 min (fasting)	Δ (30 min – 0 min) ²	Δ (exercise – 30 min) ²
Cardiac output (L/min)	PRO	5.5 (4.9, 6.0)	0.1 (-0.2, 0.4) ^a	4.9 (4.6, 5.2) ^a
	CHO	5.7 (5.1, 6.2)	0.7 (0.4, 1.0) ^b	4.7 (4.4, 5.0) ^{a,b}
	Water	5.6 (5.1, 6.2)	-0.0 (-0.3, 0.3) ^a	4.6 (4.3, 4.9) ^b
Stroke volume (mL)	PRO	83.9 (73.6, 94.3)	2.6 (-3.2, 8.5) ^a	12.8 (6.0, 19.6)
	CHO	85.5 (75.2, 95.8)	13.4 (7.6, 19.3) ^b	13.6 (6.8, 20.3)
	Water	84.5 (74.1, 94.8)	9.7 (3.9, 15.6) ^{a,b}	10.1 (3.4, 16.8)
HR (bpm)	PRO	66.7 (63.0, 70.5)	-1.0 (-3.6, 1.5) ^a	37.8 (32.5, 43.2)
	CHO	66.7 (62.9, 70.4)	-2.2 (-4.8, 0.3) ^a	39.2 (33.9, 44.5)
	Water	66.9 (63.2, 70.7)	-7.0 (-9.6, -4.5) ^b	36.6 (31.3, 42.0)
Systolic BP (mmHg)	PRO	121.0 (115.5, 126.4)	7.2 (2.7, 11.6) ^{a,b}	19.3 (14.1, 24.4)
	CHO	125.5 (120.0, 130.9)	8.8 (4.4, 13.2) ^a	17.5 (12.3, 22.7)
	Water	123.6 (118.2, 129.1)	2.1 (-2.2, 6.5) ^b	16.6 (11.4, 21.7)
Diastolic BP (mmHg)	PRO	73.1 (69.5, 76.7)	-0.2 (-2.9, 2.5)	7.6 (4.4, 10.8)
	CHO	74.4 (70.8, 77.9)	0.5 (-2.2, 3.2)	7.9 (4.7, 11.1)
	Water	73.9 (70.3, 77.5)	0.7 (-2.0, 3.4)	5.9 (2.8, 9.1)
MAP (mmHg)	PRO	90.7 (86.4, 95.0)	1.8 (-1.4, 4.9)	13.4 (9.4, 17.5)
	CHO	92.9 (88.6, 97.2)	3.0 (-0.1, 6.1)	13.2 (9.2, 17.3)
	Water	92.3 (88.0, 96.6)	1.1 (-2.0, 4.2)	12.2 (8.2, 16.3)
SVR (Wood Units)	PRO	16.8 (15.0, 18.6)	0.1 (-0.7, 0.9) ^a	-6.2 (-6.8, -5.6)
	CHO	16.9 (15.0, 18.7)	-1.4 (-2.2, -0.6) ^b	-6.2, (-6.7, -5.6)
	Water	17.1 (15.2, 18.91)	0.3 (-0.5, 1.1) ^a	-5.9 (-6.5, -5.4)
DVP-RI	PRO	72.3 (67.8, 76.9)	0.8 (-3.5, 5.2) ^a	-12.2 (-18.3, -6.2)

(%)	CHO	73.8 (69.3, 78.3)	-1.9 (-6.0, 2.1) ^a	-16.0 (-22.0, -10.0)
	Water	72.1 (67.6, 76.6)	6.4 (2.7, 10.1) ^b	-9.7 (-15.9, -3.5)
DVP-SI	PRO	6.7 (6.3, 7.2)	-0.1 (-0.3, 0.2)	0.6 (0.3, 1.0)
	CHO	6.7 (6.2, 7.1)	-0.2 (-0.4, -0.1)	0.6 (0.3, 1.0)
(m/s)	Water	6.6 (6.2, 7.1)	-0.3 (-0.6, -0.04)	0.8 (0.5, 1.2)

Values are $\bar{x}$ (95% confidence intervals); $n = 14$ (for exercise HR, BP, stroke volume and SVR, $n = 13$);

BP, blood pressure; DVP-RI, DVP-reflection index; DVP-SI, DVP-stiffness index; HR, heart rate; MAP, mean arterial pressure; SVR, systemic vascular resistance.

The point estimates and 95% CI were derived from the mixed linear model, adjusted for fasting absolute values. Values in the same column of a single outcome variable with different superscripts are significantly different, $P < 0.05$; Bonferroni correction.

LIST OF FIGURES

Fig. 1. Outline of study visits. DVP, digital volume pulse; BP, blood pressure, HR, heart rate; CO, cardiac output

Fig. 2. Changes after CHO (□), PRO (●) and water (▲) drinks from fasting (0 h) over a 30-min rest followed by changes from pre-exercise (30 min) during 12 min exercise and 15 min post-exercise in cardiac output (Panel A), mean arterial pressure (MAP; Panel B) and systemic vascular resistance (SVR; Panel C) in healthy men. Unadjusted mean values $\pm$ SEM. Adjusted least square regression models with Bonferroni correction applied: *CHO vs. PRO, $P = 0.001$; †CHO vs. water, $P < 0.001$; ‡PRO vs. water, $P < 0.025$ (A); §CHO vs. PRO, $P < 0.01$; ||CHO vs water, $P < 0.01$ (C).

Fig. 3. Changes after CHO (□), PRO (●) and water (▲) drinks from fasting (0 h) over a 30-min rest followed by changes during 12 min exercise and 15 min post-exercise in stroke volume (Panel A) and heart rate (Panel B) in healthy men. Unadjusted mean values $\pm$ SEM. Adjusted least square regression models with Bonferroni correction applied: *PRO vs. CHO, $P < 0.01$ (and PRO vs. water, $P = 0.082$); †CHO vs water, $P = 0.091$ (A); ‡PRO vs. water, $P = 0.001$; §CHO vs. water, $P < 0.01$ (B).