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Abbreviations: BMI: body mass index; CI: confidence interval; HC: high-carbohydrate; HP: high-protein; LC: low-carbohydrate; MP: moderate-protein; NA: not applicable; ND: no data; SD: standard deviation; SE: standard error; SMD: standardized mean difference; VO_{2max}: maximal oxygen uptake.

Table 1. PRISMA 2020 main checklist.

Topic	No.	Item	Location reported (or details)
TITLE			
Title	1	Identify the report as a systematic review.	Title
INTRODUCTION			
Rationale	3[a]	Describe the rationale for the review in the context of existing knowledge.	Main text – Section 1, 2nd and 3rd paragraphs
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Main text – Section 1, 3rd paragraph
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Main text – Section 2.1
Information sources	6	Specify all databases, registers, websites, organizations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Main text – Section 2.2, Appendix – Table 4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix - Table 4
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Main text – Section 2.2,
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Main text – Section 2.3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Main text – Sections 2.1 and 2.3, Appendix – Section 1, all time points extracted
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Appendix – Section 1, Tables 6 and 7, Figure 2
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Main text – Section 2.7

Topic	No.	Item	Location reported (or details)
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Main text – Section 2.4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	Main text – Section 2.4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Main text – Section 2.4
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Main text – Section 2.4
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Main text – Section 2.4
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Main text – Section 2.5
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Main text – Section 2.6
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Main text – Section 2.7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Main text – Section 2.8
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Main text – Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Appendix - Table 5
Study characteristics	17	Cite each included study and present its characteristics.	Appendix - Tables 6 and 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Appendix - Figure 1

Topic	No.	Item	Location reported (or details)
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Appendix - Figure 2
Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	Main text –Table 1, Appendix - Figure 2
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Main text – Figure 4, Appendix - Figure 2
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Appendix – Figure 2
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Appendix – Table 9
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Main text – Section 3.3, Appendix – Figure 3
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Main text – Table 1
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Main text – Sections 4.1, 4.2, 4.3, 4.4, and 4.5.
	23b	Discuss any limitations of the evidence included in the review.	Main text – Section 4.6
	23c	Discuss any limitations of the review processes used.	Main text – Section 4.6
	23d	Discuss implications of the results for practice, policy, and future research.	Main text – Sections 4.5 and 4.7
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Main text – Section 2
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Main text – Section 2
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	PROSPERO record (Whittaker and Harris, 2021)
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Main text – Funding

Topic	No.	Item	Location reported (or details)
Competing interests	26	Declare any competing interests of review authors.	Main text – Declaration of competing interest
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found:	
		Template data collection forms	Available on request
		Data extracted from included studies	Appendix – Tables 6 and 7, and Figure 2
		Data used for all analyses	Appendix - Figure 2, other data available on request
		Analytic code	Chapter 10: S1, *Cochrane handbook for systematic reviews of interventions* (Deeks and Higgins, 2021)
		Any other materials used in the review	Available on request

[a] Duplicate entries across PRISMA checklists were removed, but the original numbering was retained.

Table 2. PRISMA 2020 abstract checklist.

Topic	No.	Item	Reported?
BACKGROUND			
Objectives	2[a]	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	Yes
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	Yes
Synthesis of results	6	Specify the methods used to present and synthesize results.	Yes
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarize relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favored).	Yes
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	Yes
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	No funding
Registration	12	Provide the register name and registration number.	Yes

[a] Duplicate entries across PRISMA checklists were removed, but the original numbering was retained.

Table 3. PRISMA 2021 search extension checklist.

Topic	No.	Item	Location reported (or details)
INFORMATION SOURCES AND METHODS			
Objectives	1	Name each individual database searched, stating the platform for each.	Appendix – Table 4
Database name	2	If databases were searched simultaneously on a single platform, state the name of the platform, listing all of the databases searched.	Databases searched individually
Study registries	3	List any study registries searched.	Appendix – Table 4
Online resources and browsing	4	Describe any online or print source purposefully searched or browsed (e.g., tables of contents, print conference proceedings, web sites), and how this was done.	None searched, besides preliminary scoping searches on Google Scholar.
Citation searching	5	Indicate whether cited references or citing references were examined, and describe any methods used for locating cited/citing references (e.g. browsing reference lists, using a citation index, setting up email alerts for references citing included studies).	Main text – Section 2.2
Contacts	6	Indicate whether additional studies or data were sought by contacting authors, experts, manufacturers, or others.	Main text – Section 2.3, Appendix – Table 5
Other methods	7	Describe any additional information sources or search methods used.	Main text – Figure 1
SEARCH STRATEGIES			
Full search strategies	8	Include the search strategies for each database and information source, copied and pasted exactly as run.	Appendix – Table 4
Limits and restrictions	9	Specify that no limits were used, or describe any limits or restrictions applied to a search (e.g. date or time period, language, study design) and provide justification for their use.	Main text – Section 2.2
Search filters	10	Indicate whether published search filters were used (as originally designed or modified), and if so, cite the filter(s) used.	Appendix – Table 4
Prior work	11	Indicate when search strategies from other literature reviews were adapted or reused for a substantive part or all of the search, citing the previous review(s).	Not used
Updates	12	Report the methods used to update the search(es) (e.g. rerunning searches, email alerts).	Search run only once
Dates of searches	13	For each search strategy, provide the date when the last search occurred.	Appendix – Table 4

Topic	No.	Item	Location reported (or details)
PEER REVIEW			
Peer review	14	Describe any search peer review process.	No peer review
MANAGING RECORDS			
Total records	15	Document the total number of records identified from each database and other information sources.	Main text – Figure 1
Deduplication	16	Describe the processes and any software used to deduplicate records from multiple database searches and other information sources.	Main text – Section 2.2

Table 4. Database searches.

Database	Search date	Filters used	Search terms
MEDLINE (via PubMed)	25/5/21	Male Adult: 19+ years	(hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens) AND (low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein) AND (diet OR dietary)
CENTRAL	25/5/21	Trials Search word variations	All text: (hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens) AND (low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein) AND (diet OR dietary)
CINAHL Complete (via EBSCO)	25/5/21	Apply equivalent subjects All adult Male	(hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens) AND (low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein)
SPORTDiscus with full text (via EBSCO)	25/5/21	Apply equivalent subjects	(hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens) AND (low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein)
ClincalTrials.gov	25/5/21	Male Adult (18-64) Older Adult (65+) Completed Accepts healthy volunteers	Condition: low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein Other terms: hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens
ICTRP	25/5/21	With results only	hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens AND low fat OR high fat OR high protein OR low protein OR high carbohydrate OR low carbohydrate OR ketogenic OR carbohydrate restricted OR carbohydrate limited OR dietary fat OR dietary carbohydrate OR dietary protein

Database	Search date	Filters used	Search terms
Open Grey	25/5/21	No filters	(hypogonadism OR testosterone OR cortisol OR sex hormone OR sex hormones OR androgen OR androgens) AND (diet OR dietary OR macronutrient OR macronutrients OR nutrition OR nutritional)
Google Scholar (search 1)	26/5/21	No filters	testosterone men "low carbohydrate"
Google Scholar (search 2)	26/5/21	No filters	cortisol men "low carbohydrate"

1. Additional considerations regarding data extraction

Krings 2021

This study was originally a parallel study with one group receiving a low-carbohydrate (LC) diet, and the other group a LC diet plus carbohydrate supplements around workouts (Krings et al., 2021). The latter group was excluded in the data extraction and meta-analyses, as the carbohydrate supplementation made the group incomparable with the other studies. This in effect turned the study into a single-arm crossover study, and was analysed accordingly.

Burke 2020

This study was conducted over three separate time periods, using some of the same participants, which in effect made it both a crossover and parallel study. The study included two high-carbohydrate (HC) diet groups: a normal HC diet and a periodised HC diet (Burke et al., 2017, 2020). The latter group was excluded, as the periodisation of carbohydrate intake made it incomparable to the other included studies. This study used 13 of the same participants as Burke 2021 (Burke et al., 2021). To avoid double counting participants, these participants were excluded from the Burke 2020 data.

The authors of Burke 2020 supplied the individual participant data for both cortisol and testosterone, as this data is not yet published. Mean ± SD (change scores) were calculated for LC and HC diets using all of the participant observations provided.

Due to the complexity of this study, sample and diet characteristics data were drawn from the first two out of three trial periods only. This meant the data included five participants excluded, and excluded four participants included, in the meta-analyses. However, as all samples within this study were homogenous, the extracted data could be fairly generalized to the sample used in the meta-analyses.

Bisschop 2000

This study had two HC diets that were eligible (Bisschop et al., 2000). One of the HC diets had 0% fat intake, making it unsuitable for comparison with the other studies. Therefore, this diet was excluded in favour of the 'control' diet, which had 41% fat intake. The results of the two HC diets were not significantly different.

Jaffe 2018

The main report of this study was published in a possible predatory journal (Beall, 2021; Jaffe et al., 2018). The report itself was well written, and the study was methodologically sound. The lead author was contacted and confirmed the authenticity of the study. The author also replied that the study was done as his Master's thesis at Springfield College, USA (Jaffe, 2013). The thesis was independently sourced, which confirmed the authenticity of the study.

Witt 1993

This study had two subgroups, one that exercised during the dietary interventions and one that was sedentary (Witt et al., 1993). These subgroups were combined for the meta-analyses. Also, this study reported both day and night-time cortisol measurements. The daytime cortisol measurements were used for the 0hr post-exercise cortisol meta-analysis, as these were comparable to the other studies, which all reported daytime measurements.

The study had two eligible HC diets. The HC diet with the highest carbohydrate intake (75%) was used, to maximise the difference in carbohydrate intake between intervention diets. There was no significant difference in outcomes between the two HC diets.

Tsai 1993

This study had two eligible HC diets (Tsai et al., 1993). The intervention diets lacked a sufficient washout period. Therefore, the second HC diet ('carbohydrate rich diet ad libitum (CHO)') was excluded to provide an adequate washout period, for the majority of participants. The results of the two HC diets were not significantly different, however there was a non-significant increase in cortisol on the excluded HC diet.

Galbo 1979

This study included an exercise to exhaustion protocol, with blood samples taken every 30 min (Galbo et al., 1979). To standardize the exercise duration between LC and HC diets (LC, 61.5 min; HC, 106 min), 60 min cortisol values were extracted for both diets, for use in the meta-analyses. Also, this study had two identical LC diet periods. To maximise precision, a mean of these two diet periods was used.

Table 5. Excluded studies.

Author & year	Reason for exclusion	Additional details
Anderson 1991 (Anderson et al., 1991; Thorp et al., 1990)	LC diet, carbohydrate intake >35%	The LC diet was <300 g/day carbohydrate and ~3000 kcal/day. Thus, using 299 g/day carbohydrate, carbohydrate intake was ~39.9%.
Ebbeling 2018 (Ebbeling et al., 2018, 2020; Ludwig, 2014)	Weight loss >3 kg	Before the HC and LC diets, the study included a 12% 'run-in' weight loss diet, making it too methodically heterogeneous to compare with the other included studies.
Helie 1985 (Hélie et al., 1985)	>15% difference in energy intake between HC & LC diets	Participants on the LC diet fasted before testing, whereas on the HC diet they ate breakfast. Since, the diets were one day long, this difference in food intake represented ~33% difference in energy intake.
Joy 2017 (Joy, 2017)	No outcome data	Based on the trial protocol this study appears eligible. However, to the best our knowledge the results are not yet publicly available. The author was emailed to request the results, but did not respond.
Kirwan 1990 (Kirwan et al., 1988, 1990)	LC diet, carbohydrate intake >35%	The LC diet was ~260 g/day carbohydrate. Energy intake was not reported, but the diets were 'eucaloric'. Using the available information and the Mifflin-St Jeor equation (Mifflin et al., 1990), multiplied by activity factor 1.725, energy intake was ~2812 kcal/day, making carbohydrate intake ~37%.
Reed 1987 (Reed et al., 1987)	LC diet, carbohydrate intake >35%	The LC diet was >100 g/day fat intake. Protein, carbohydrate, and energy intake were not reported. Protein intake was estimated to be 15.5%, based on a contemporary sample (Cohen et al., 2015). Energy intake was estimated to be 2500 kcal/day (Public Health England, 2016), as the participants were 97 ± 7% ideal bodyweight and the diets were 'weight-maintaining'. Using these figures and 101 g/day carbohydrate, carbohydrate intake was ~48.1%.
Remer 1998 (Remer et al., 1998; Remer and Manz, 1994)	LC diet, carbohydrate intake >35%	For the male participants, the LC diet was 2457 kcal/day and ~256 g/day carbohydrate, including ~30 g/day carbohydrate from supplements, making carbohydrate intake ~41.7%.

Author & year	Reason for exclusion	Additional details
Sims 1974 (Sims et al., 1968, 1974)	No outcome data	This study reported measuring plasma and urinary cortisol. However, only the results for urinary cortisol were presented. Due to the age of the study, the authors were unable to be contacted to request the results.
Volek 2001 (Volek et al., 2000, 2001)	Weight loss >3 kg	Mean weight loss was 4.2 kg on the LC diet.
Wang 2005 (Wang et al., 2005)	LC diet, carbohydrate intake >35%	The LC diet was 37.9% fat. Carbohydrate and protein intake were not reported. Protein intake was estimated to be 15.6%, based on a contemporary sample (Cohen et al., 2015). Thus, carbohydrate intake was ~46.5%.
Wilson 2020 (Rauch et al., 2014; Silva, 2014; Wilson et al., 2020)	Carbohydrate loading on LC diet	The last week of the LC diet included carbohydrate loading. Outcome data before this point was not available.

HC: high-carbohydrate; LC: low-carbohydrate.

Table 6. Characteristics of included studies.

Author & year[a]	Study design	Sample size	Age	Body mass (kg)	BMI (kg/m^2)	Exercise during intervention[b]	Duration (min) x intensity (%VO_{2max}) of exercise before post-exercise cortisol[c]	Duration of LC diet (days)	Duration of HC diet (days)	Change in body mass during LC diet (kg)	Change in body mass during HC diet (kg)
Paoli 2021 (Paoli, 2020; Paoli et al., 2021)	Parallel	19	27.4 ± 10.5	87.8 ± 13.3	26.8 ± 1.9	Resistance	NA	56	56	-0.88	1.33
Toma 2009 (Toma, 2009; Werner, 2006)[d]	Parallel	17	23.3 ± 3.3	77.9 ± 11.4	24.2	Aerobic	NA	49	49	-1.57	-0.11
Volek 2002 (Volek et al., 2002)	Parallel	20	36 ± 11.9	81.7 ± 10.5	ND	Mixed (n = 14) Aerobic (n = 5) Sedentary (n = 1)	NA	42	42	-2.2	0.4
Shaw 2021 (Shaw et al., 2019, 2021)	Crossover (AB/BA)	8	29.6 ± 5.1	73.1 ± 6.9	22.4 ± 1.7	Aerobic	232 x 70 (running)	31	31	-1.4	-0.2
Durkalec-Michalski 2021 (Durkalec-Michalski et al., 2019, 2021)	Crossover (AB)	11	28.5 ± 5.3	81.3 ± 9.5	26	Mixed	18 x ~60-100 (cycling)	28	14 (baseline diet)	-1.2	0

Author & year[a]	Study design	Sample size	Age	Body mass (kg)	BMI (kg/m^2)	Exercise during intervention[b]	Duration (min) x intensity (%VO_{2max}) of exercise before post-exercise cortisol[c]	Duration of LC diet (days)	Duration of HC diet (days)	Change in body mass during LC diet (kg)	Change in body mass during HC diet (kg)
Michalczyk 2019 (Michalczyk et al., 2019)	Crossover (AB)	15	23.5 ± 2.2	92.2 ± 5.1	25 ± 1.9	Mixed	NA	28	baseline diet	-1.8	0
Waldman 2020 (Waldman et al., 2019, 2020)	Crossover (AB)	15	33.5 ± 9.7	89.1 ± 12.7	28.1 ± 3.5	Resistance (n = 14) Mixed (n = 1)	NA	28	15 (baseline diet)	-2.64	0.1
Zajac 2014 (Zajac et al., 2014)	Crossover (AB/BA)	8	28.3 ± 3.9	80.3 ± 7.4	24.9 ± 3	Aerobic	105 x ~64-86 (cycling)	28	28	-2.08	-0.2
Krings 2021 (Krings, 2018; Krings et al., 2021)	Crossover (AB)	9	19.7 ± 1	83.8 ± 12.6	26.1	Mixed	NA	28	14 (baseline diet)	0.6	0
Burke 2020 (Burke, 2019; Burke et al., 2017, 2020; Heikura et al., 2019; McKay, 2020; Mirtschin et al., 2018)	Parallel & crossover (A/B/AB)	13	26.9 ± 3.9[e]	65.3 ± 7.7[e]	ND	Aerobic	NA	21	21	-1.8[e]	-0.6[e]

Author & year[a]	Study design	Sample size	Age	Body mass (kg)	BMI (kg/m^2)	Exercise during intervention[b]	Duration (min) x intensity (%VO_{2max}) of exercise before post-exercise cortisol[c]	Duration of LC diet (days)	Duration of HC diet (days)	Change in body mass during LC diet (kg)	Change in body mass during HC diet (kg)
Gray 1990 (Gray et al., 1990)[d]	Crossover (AB)	10	19-41 (range)	80.3 ± 8.2	ND	Mixed	NA	18	12	-1.9	0
Waldman 2018 (Waldman et al., 2018)	Crossover (AB)	11	21.6 ± 1.9	88.9 ± 11.3	27.6	Mixed	NA	15	baseline diet	-1.2	0
Terink 2021 (Mensink, 2019; Terink et al., 2021)	Crossover (AB/BA)	14	32.9 ± 8.2	76.4 ± 5.4	23.1 ± 1.4	Aerobic (n = 8) Mixed (n = 4) Resistance (n = 2)	90 x 70 (cycling)	14	14	-2.4	-1.3
Bisschop 2000 (Bisschop et al., 2000)	Crossover (ABC/BAC/ CAB)[f]	6	29-55 (range)	ND	21-26 (range)	Sedentary	NA	11	11	ND	ND
Anderson 1987 (Alvares et al., 1976; Anderson et al., 1987)	Crossover (AB)	7	22-43 (range)	64-72 (range)	ND	Mixed	NA	10	10	'no significant changes'	'no significant changes'
Jaffe 2018 (Jaffe, 2013; Jaffe et al., 2018)[d]	Crossover (AB/BA)	10	22.6 ± 4.1	81.3 ± 10.8	26.6	Mixed	NA	7	7	-0.4	-0.5

Author & year[a]	Study design	Sample size	Age	Body mass (kg)	BMI (kg/m^2)	Exercise during intervention[b]	Duration (min) x intensity (%VO_{2max}) of exercise before post-exercise cortisol[c]	Duration of LC diet (days)	Duration of HC diet (days)	Change in body mass during LC diet (kg)	Change in body mass during HC diet (kg)
Burke 2021 (Burke, 2018; Burke et al., 2021; McKay, 2020; Mirtschin et al., 2018)	Parallel	13	30.3 ± 4.3	66.2 ± 7.6	ND	Aerobic	125 x 75 (race walking)	6	6	-1.3	-0.7
Witt 1993 (Witt et al., 1993)	Crossover (ABC/BAC/ CAB/CBA)[g]	15	23.1 ± 4	74.2 ± 7.6	24.8	Aerobic (n = 8) Sedentary (n = 7)	NA	5	5	ND	ND
Lane 2010 (Duke Jr., 2008; Lane, 2009; Lane et al., 2010)	Parallel	20	25.8 ± 5.1	74.9 ± 7.3	23.2	Aerobic	60 x 75 (cycling)	4	4	ND	ND
Galbo 1979 (Galbo et al., 1979)	Crossover (ABA)[h]	7	26	77	22.7	Aerobic	60 x 70 (running)	4	4	-2	-0.6
Gleeson 1998 (Gleeson et al., 1998)	Parallel	12	25 ± 6.9	78.3 ± 11.8	24.4	Aerobic	60 x 70 (cycling)	3	3	ND	ND
Bishop 2001 (Bishop et al., 2001a, 2001b)	Crossover (AB/BA)	12	26 ± 6.9	73.4 ± 9	23.2	Aerobic	90 x ~70-93 (cycling)	3	3	-0.5	0.8

Author & year[a]	Study design	Sample size	Age	Body mass (kg)	BMI (kg/m^2)	Exercise during intervention[b]	Duration (min) x intensity (%VO_{2max}) of exercise before post-exercise cortisol[c]	Duration of LC diet (days)	Duration of HC diet (days)	Change in body mass during LC diet (kg)	Change in body mass during HC diet (kg)
Tsai 1993 (Tsai et al., 1993)	Crossover (ABC/ACB)[i]	4	25.5 ± 1.7	78.3 ± 3.3	23.6 ± 1.3	Mixed	NA	3	baseline diet	no significant changes	no significant changes
Langfort 1996 (Langfort et al., 1994, 1996)	Crossover (AB)	8	22 ± 0.9	69 ± 9	23.1	Aerobic	27 x ~60-100 (cycling)	3	3	ND	ND
Langfort 2001 (Langfort et al., 2001)	Crossover (AB)	9	22 ± 0.9	77.1 ± 2.8	24.6	Aerobic	NA	3	3	ND	ND
Lima-Silva 2011 (Lima-Silva et al., 2011)	Crossover (AB/BA)	6	25.8 ± 5.8	70.9 ± 6.3	22.8	Aerobic	15 x ~60-90 (cycling)	2	2	ND	ND
Mitchell 1998 (Mitchell et al., 1998)	Crossover (AB/BA)	10	24.7 ± 15.2	79.32 ± 23.6	24.8	Aerobic	60 x 75 (cycling)	2	2	-0.85	0.08

[a] Unless otherwise stated, all data pertains to the participants and interventions included in the meta-analyses.
[b] Aerobic (≥80% aerobic training), resistance (≥80% resistance training), mixed (combination of aerobic, resistance, sport, or unspecified exercise).
[c] All exercise was aerobic. x - x indicates increasing intensity during exercise. Where VO_{2max} was not provided, it was estimated from the available data and indicated using ~.
[d] Studies from grey literature.
[e] Data includes five participants excluded, and excludes for participants included, in the meta-analyses.
[f] Two HC diets eligible. Data extracted for 'control' diet.
[g] Two HC diets eligible. Data extracted for 'high carbohydrate (low fat) diet'.

[h] Two LC diets eligible. Data extracted both LC diets, and a mean presented.
[i] Two HC diets eligible. Data extracted for 'western type food (N)' diet.
Values presented as mean ± SD.
BMI: body mass index; HC: high-carbohydrate; LC: low-carbohydrate; NA: not applicable; ND: no data; SD: standard deviation; VO_{2max}: maximal oxygen uptake.

Table 7. Characteristics of study diets.

Study[a]	LC diet							HC diet						
	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)
Paoli 2021	5	68	24.7	ND	ND	ND	3443.7	55	20	25	ND	ND	ND	3529.7
Toma 2009	30.6	38.5	29.9	ND	ND	ND	2605.5	57.5	25.4	14.2	ND	ND	ND	2540.5
Volek 2002	8	61	30	ND	ND	741	2333.5	58	26	16	ND	ND	155	1949
Shaw 2021[b]	4.1	77.7	18.2	23.3	24	ND	3279.4	42.9	38.5	18.6	41.1	128	ND	3121.7
Durkalec-Michalski 2021[b]	4	77	18	8.9	2	637	2955	44	36	19	34.7	37.3	497	2645
Michalczyk 2019	10	59	31	ND	ND	ND	3758	54	31	15	ND	ND	ND	3740
Waldman 2020	21	48.5	30.5	15.3	30	221.3	1759	47	35	18	14	87	323	2090
Zajac 2014	15	70	15	ND	ND	ND	3865	50	30	20	ND	ND	ND	3865
Krings 2021	22.7	51.3	26	ND	ND	ND	2944.6	44.2	32.4	22.4	ND	ND	ND	2637.9
Burke 2020[bc]	3.8	78.8	16.1	ND	25	931	3472.8	62.4	19.7	15.7	ND	278	331	3518.2
Gray 1990 (ranges shown)	7 - 9	73 - 76	16 - 20	ND	ND	ND	3004	48 - 53	35 - 36	12 - 16	ND	ND	ND	3054
Waldman 2018	14.3	58	28	13	30	ND	2457.7	52	29	19	14	76	ND	2357

Study[a]	LC diet							HC diet						
	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)
Terink 2021	8	73	16	28	ND	699	3104	49	33	15	41	ND	165	3075
Bisschop 2000[d]	2	83	15	ND	ND	ND	ND	44	41	15	ND	ND	ND	ND
Anderson 1987	35	21	44	ND	ND	ND	ND	70	20	10	ND	ND	ND	ND
Jaffe 2018	7	39	55	ND	ND	ND	2271.2	55	20	25	ND	ND	ND	2294
Burke 2021	4	80	16	ND	ND	ND	3530	66	20	15	ND	ND	ND	3852
Witt 1993	15	70	15	ND	ND	ND	ND	75	10	15	ND	ND	ND	ND
Lane 2010	31.9	ND	ND	ND	ND	ND	2804.1	58.5	ND	ND	ND	ND	ND	3226.7
Galbo 1979[d]	10.5	76	13.5	ND	ND	ND	2641	77	9.5	13.5	ND	ND	ND	2904
Gleeson 1998	7	68	25	ND	ND	ND	2221.3	75	17	8	ND	ND	ND	2006.3
Bishop 2001	8.7	68.5	22.3	ND	ND	ND	3343.8	76.7	10.2	12.2	ND	ND	ND	2913.9
Tsai 1993	15	60	25	ND	ND	ND	2500 - 3000 (range)	45	40	15	ND	ND	ND	2500 - 3000 (range)
Langfort 1996	5	50	45	ND	ND	ND	2208	50	30	20	ND	ND	ND	2208

Study[a]	LC diet							HC diet						
	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)	Carbo-hydrate (%)	Fat (%)	Protein (%)	Fiber (g)	Sugar (g)	Cholesterol (mg)	Energy (kcal)
Langfort 2001	5	50	45	ND	ND	ND	2395.6	50	30	20	ND	ND	ND	2395.6
Lima-Silva 2011	10	35	55	ND	ND	ND	ND	80	10	10	ND	ND	ND	ND
Mitchell 1998	4.4	66.9	27.8	ND	ND	ND	3080	79.1	9.7	12.9	ND	ND	ND	3056

[a] Unless otherwise stated, all data pertains to the participants and interventions included in the meta-analyses.
[b] Studies reported data on micronutrient intakes.
[c] Data includes five participants excluded, and excludes four participants included, in the meta-analyses.
[d] Studies used liquid intervention diets.
Values presented as mean.
HC: high-carbohydrate; LC: low-carbohydrate; ND: no data.

Figure 1. Risk of bias ratings for studies.

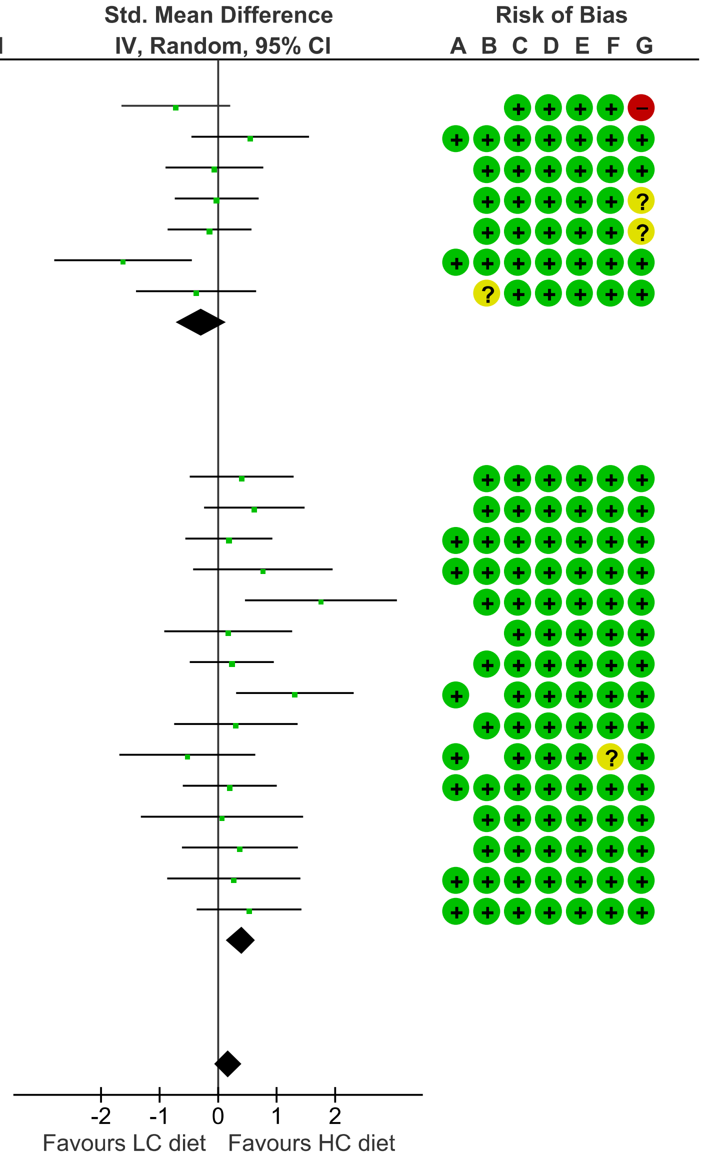
Table 8. Reasons for high and medium bias ratings.

Study	Bias domain	Bias rating	Reason
Michalczyk 2019	Bias due to confounding variables	Medium	During the LC diet period, the participants lived in a dormitory which may have altered their sleep habits, psychological stress levels, and social activity; all of which are possible confounding variables. The participants most likely did not live in a dormitory during the HC diet period, since this was their habitual diet. The author was contacted to clarify this point, but did not respond.
Waldman 2020	Bias due to confounding variables	Medium	The LC vs HC diet was 15.8% lower in energy intake, and the difference in weight change was -2.74 kg. These were the highest differences in energy intake and weight change of any included study, and somewhat an outlier. The weight loss and reduced energy intake on the LC diet may have confounded the results.
Krings 2020	Bias due to confounding variables	Medium	During the intervention diets resistance training volume was matched, whereas interval training volume was higher on the LC diet. This small difference in exercise volume may have confounded the results.
Burke 2020	Bias due to period and carryover effects	Medium	The participant allocation between diets and time periods was not balanced, which put the results at risk of period effects.
Gleeson 1998	Bias due to selection of reported result	Medium	This parallel study presented baseline data as combined (n = 12), but post-intervention data as split (n = 6, x2). Presenting the data in this way made it impossible to extract change from baseline scores, even though this data was available to the study's authors. This was most likely an honest error, but still raises some concerns over selective reporting. The lead author was contacted to request change from baseline data, but did not respond.
Volek 2002	Bias due to confounding variables	High	The LC diet group received a daily multi-vitamin and mineral supplement, whereas the HC diet group did not. This difference in micronutrient supplementation is likely to have confounded the results.

HC: high-carbohydrate; LC: low-carbohydrate.

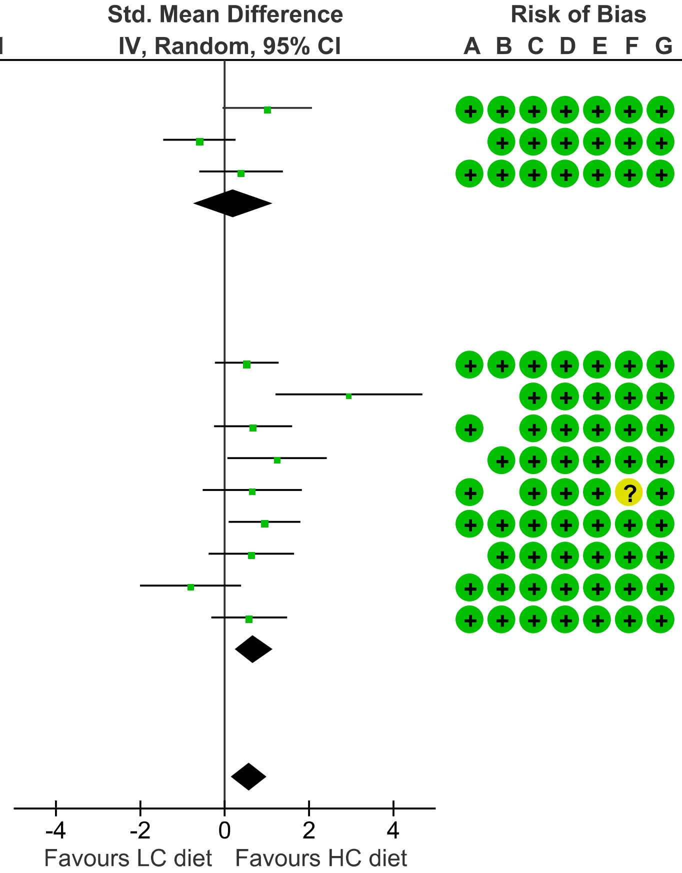
A. Cortisol, resting, long- vs short-term LC diets.

Study or Subgroup	LC diet Mean	LC diet SD	LC diet Total	HC diet Mean	HC diet SD	HC diet Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Long-term LC diets (≥3 weeks)								
Volek 2002	-103	247	12	50	98	8	4.7%	-0.72 [-1.65, 0.21]
Shaw 2021	24	81.4	8	-38	127	8	4.2%	0.55 [-0.45, 1.55]
Durkalec-Michalski 2021	285.7	84.7	11	290.4	56.8	11	5.4%	-0.06 [-0.90, 0.77]
Michalczyk 2019	16.22	6.4	15	16.38	6.81	15	6.5%	-0.02 [-0.74, 0.69]
Waldman 2020	23.8	5	15	24.5	4.2	15	6.5%	-0.15 [-0.86, 0.57]
Zajac 2014	553	49	8	649	62	8	3.3%	-1.62 [-2.80, -0.45]
Burke 2020	35.23857	101.6751	7	73.48111	90.40971	8	4.1%	-0.38 [-1.40, 0.65]
Subtotal (95% CI)			**76**			**73**	**34.7%**	**-0.28 [-0.70, 0.15]**
Heterogeneity: Tau² = 0.12; Chi² = 9.40, df = 6 (P = 0.15); I² = 36%								
Test for overall effect: Z = 1.28 (P = 0.20)								
1.1.2 Short-term LC diets (<3 weeks)								
Gray 1990	105.1	36.8	10	91.4	27.7	10	5.0%	0.40 [-0.48, 1.29]
Waldman 2018	253.9	46.4	11	224.7	44.5	11	5.2%	0.62 [-0.24, 1.48]
Terink 2021	510.3	229.7378	14	465.7	242.8336	14	6.2%	0.18 [-0.56, 0.93]
Bisschop 2000	265	63.68673	6	217	51.43928	6	3.3%	0.77 [-0.43, 1.96]
Anderson 1987	10.6	1.058301	7	7.74	1.878483	7	2.9%	1.76 [0.46, 3.05]
Burke 2021	0.46	3.3	7	-0.07	2.26	6	3.7%	0.17 [-0.92, 1.26]
Witt 1993	8.933	2.5799	15	8.34	2.3427	15	6.5%	0.23 [-0.48, 0.95]
Lane 2010	27.64	7.91	8	19.4	4.4	12	4.2%	1.31 [0.31, 2.32]
Galbo 1979	21.6	100.0094	7	-14.4	120.6463	7	3.9%	0.30 [-0.75, 1.36]
Gleeson 1998	460	293.9388	6	615	247.3985	6	3.4%	-0.53 [-1.69, 0.63]
Bishop 2001	398	114	12	376	99	12	5.7%	0.20 [-0.60, 1.00]
Tsai 1993	458	255	4	443	114	4	2.6%	0.07 [-1.32, 1.45]
Langfort 1996	233.63	107.8479	8	190.11	113.4765	8	4.3%	0.37 [-0.62, 1.36]
Lima-Silva 2011	497.5	307.4	6	431.4	97.9	6	3.5%	0.27 [-0.87, 1.41]
Mitchell 1998	42.1	211.5564	10	-75.3	213.1375	10	4.9%	0.53 [-0.37, 1.42]
Subtotal (95% CI)			**131**			**134**	**65.3%**	**0.41 [0.16, 0.66]**
Heterogeneity: Tau² = 0.00; Chi² = 11.75, df = 14 (P = 0.63); I² = 0%								
Test for overall effect: Z = 3.22 (P = 0.001)								
Total (95% CI)			**207**			**207**	**100.0%**	**0.18 [-0.06, 0.42]**
Heterogeneity: Tau² = 0.11; Chi² = 30.77, df = 21 (P = 0.08); I² = 32%								
Test for overall effect: Z = 1.44 (P = 0.15)								
Test for subgroup differences: Chi² = 7.51, df = 1 (P = 0.006), I² = 86.7%								



B. Cortisol, 0 hr post-exercise, long- vs short-term LC diets.

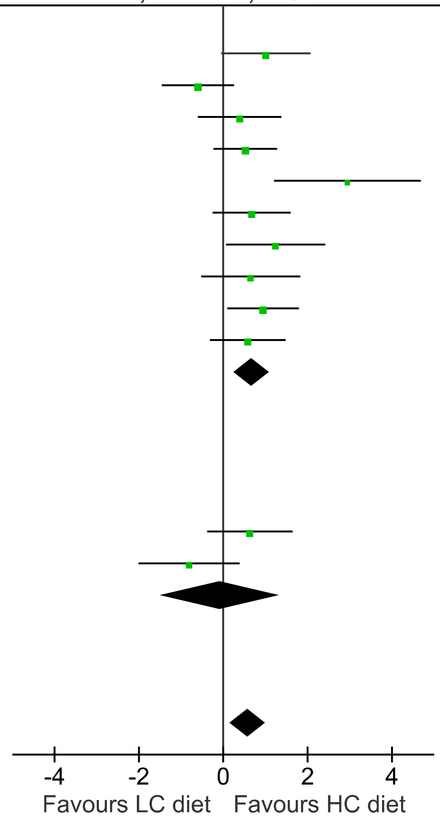
Study or Subgroup	LC diet Mean	LC diet SD	LC diet Total	HC diet Mean	HC diet SD	HC diet Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.2.1 Long-term LC diets (≥3 weeks)								
Shaw 2021	188	175	8	-7	190	8	8.1%	1.01 [-0.05, 2.07]
Durkalec-Michalski 2021	303.3	80.2	11	368.1	123.7	11	9.8%	-0.60 [-1.46, 0.26]
Zajac 2014	676	65	8	650	62	8	8.6%	0.39 [-0.61, 1.38]
Subtotal (95% CI)			**27**			**27**	**26.5%**	**0.23 [-0.71, 1.17]**
Heterogeneity: Tau² = 0.45; Chi² = 5.66, df = 2 (P = 0.06); I² = 65%								
Test for overall effect: Z = 0.47 (P = 0.64)								
1.2.2 Short-term LC diets (<3 weeks)								
Terink 2021	669	243	14	555	173	14	10.9%	0.52 [-0.23, 1.28]
Burke 2021	12.75	3.16	7	0.28	4.71	6	4.3%	2.94 [1.20, 4.68]
Lane 2010	27.89	6.75	8	22.47	8.25	12	9.2%	0.67 [-0.25, 1.60]
Galbo 1979	752	190.4941	7	500.6	188.9066	7	7.2%	1.24 [0.06, 2.42]
Gleeson 1998	793	578.0796	6	501	93.08061	6	7.2%	0.65 [-0.52, 1.83]
Bishop 2001	711	203	12	560	81	12	9.9%	0.94 [0.09, 1.80]
Langfort 1996	246.09	102.6153	8	159.56	152.1977	8	8.4%	0.63 [-0.38, 1.64]
Lima-Silva 2011	354.4	151.5	6	519.4	218.1	6	7.0%	-0.81 [-2.01, 0.39]
Mitchell 1998	793.8	255.8283	10	638.8	255.8283	10	9.4%	0.58 [-0.32, 1.48]
Subtotal (95% CI)			**78**			**81**	**73.5%**	**0.71 [0.26, 1.16]**
Heterogeneity: Tau² = 0.20; Chi² = 13.90, df = 8 (P = 0.08); I² = 42%								
Test for overall effect: Z = 3.07 (P = 0.002)								
Total (95% CI)			**105**			**108**	**100.0%**	**0.58 [0.17, 0.99]**
Heterogeneity: Tau² = 0.26; Chi² = 22.18, df = 11 (P = 0.02); I² = 50%								
Test for overall effect: Z = 2.75 (P = 0.006)								
Test for subgroup differences: Chi² = 0.82, df = 1 (P = 0.37), I² = 0%								



C. Cortisol, 0 hr post-exercise, MP- vs HP-LC diets.

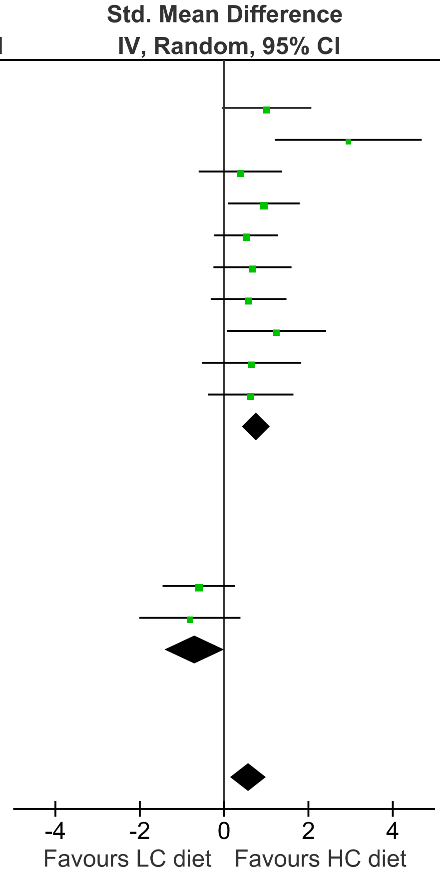
	LC diet			HC diet				Std. Mean Difference	Risk of Bias						
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
1.3.1 MP-LC diets (<35%)															
Shaw 2021	188	175	8	-7	190	8	8.1%	1.01 [-0.05, 2.07]	+	+	+	+	+	+	+
Durkalec-Michalski 2021	303.3	80.2	11	368.1	123.7	11	9.8%	-0.60 [-1.46, 0.26]		+	+	+	+	+	+
Zajac 2014	676	65	8	650	62	8	8.6%	0.39 [-0.61, 1.38]	+	+	+	+	+	+	+
Terink 2021	669	243	14	555	173	14	10.9%	0.52 [-0.23, 1.28]	+	+	+	+	+	+	+
Burke 2021	12.75	3.16	7	0.28	4.71	6	4.3%	2.94 [1.20, 4.68]			+	+	+	+	+
Lane 2010	27.89	6.75	8	22.47	8.25	12	9.2%	0.67 [-0.25, 1.60]	+		+	+	+	+	+
Galbo 1979	752	190.4941	7	500.6	188.9066	7	7.2%	1.24 [0.06, 2.42]		+	+	+	+	+	+
Gleeson 1998	793	578.0796	6	501	93.08061	6	7.2%	0.65 [-0.52, 1.83]	+		+	+	+	?	+
Bishop 2001	711	203	12	560	81	12	9.9%	0.94 [0.09, 1.80]	+	+	+	+	+	+	+
Mitchell 1998	793.8	255.8283	10	638.8	255.8283	10	9.4%	0.58 [-0.32, 1.48]	+	+	+	+	+	+	+
Subtotal (95% CI)			**91**			**94**	**84.5%**	**0.68 [0.25, 1.12]**							
Heterogeneity: Tau² = 0.22; Chi² = 17.02, df = 9 (P = 0.05); I² = 47%															
Test for overall effect: Z = 3.10 (P = 0.002)															
1.3.2 HP-LC diets (≥35%)															
Langfort 1996	246.09	102.6153	8	159.56	152.1977	8	8.4%	0.63 [-0.38, 1.64]		+	+	+	+	+	+
Lima-Silva 2011	354.4	151.5	6	519.4	218.1	6	7.0%	-0.81 [-2.01, 0.39]	+	+	+	+	+	+	+
Subtotal (95% CI)			**14**			**14**	**15.5%**	**-0.05 [-1.46, 1.36]**							
Heterogeneity: Tau² = 0.72; Chi² = 3.24, df = 1 (P = 0.07); I² = 69%															
Test for overall effect: Z = 0.07 (P = 0.94)															
Total (95% CI)			**105**			**108**	**100.0%**	**0.58 [0.17, 0.99]**							
Heterogeneity: Tau² = 0.26; Chi² = 22.18, df = 11 (P = 0.02); I² = 50%															
Test for overall effect: Z = 2.75 (P = 0.006)															
Test for subgroup differences: Chi² = 0.96, df = 1 (P = 0.33), I² = 0%															

Std. Mean Difference
IV, Random, 95% CI



D. Cortisol, 0 hr post-exercise, long- vs short-duration exercise.

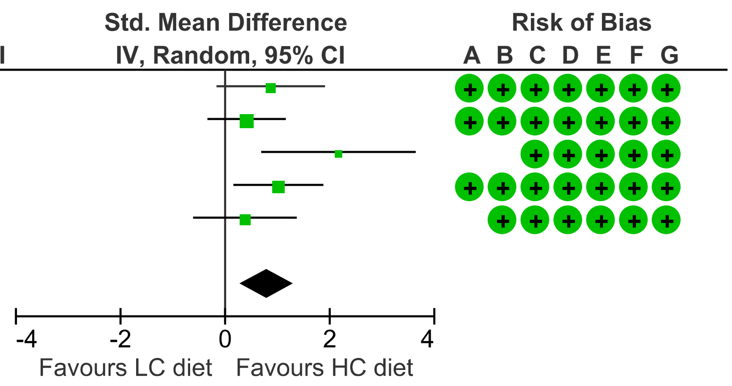
Study or Subgroup	LC diet Mean	LC diet SD	LC diet Total	HC diet Mean	HC diet SD	HC diet Total	Weight	Std. Mean Difference IV, Random, 95% CI	Risk of Bias A	B	C	D	E	F	G
1.4.1 Long-duration exercise (≥20min)															
Shaw 2021	188	175	8	-7	190	8	8.1%	1.01 [-0.05, 2.07]	+	+	+	+	+	+	+
Burke 2021	12.75	3.16	7	0.28	4.71	6	4.3%	2.94 [1.20, 4.68]			+	+	+	+	+
Zajac 2014	676	65	8	650	62	8	8.6%	0.39 [-0.61, 1.38]	+	+	+	+	+	+	+
Bishop 2001	711	203	12	560	81	12	9.9%	0.94 [0.09, 1.80]	+	+	+	+	+	+	+
Terink 2021	669	243	14	555	173	14	10.9%	0.52 [-0.23, 1.28]	+	+	+	+	+	+	+
Lane 2010	27.89	6.75	8	22.47	8.25	12	9.2%	0.67 [-0.25, 1.60]	+		+	+	+	+	+
Mitchell 1998	793.8	255.8283	10	638.8	255.8283	10	9.4%	0.58 [-0.32, 1.48]	+	+	+	+	+	+	+
Galbo 1979	752	190.4941	7	500.6	188.9066	7	7.2%	1.24 [0.06, 2.42]		+	+	+	+	+	+
Gleeson 1998	793	578.0796	6	501	93.08061	6	7.2%	0.65 [-0.52, 1.83]	+		+	+	+	?	+
Langfort 1996	246.09	102.6153	8	159.56	152.1977	8	8.4%	0.63 [-0.38, 1.64]		+	+	+	+	+	+
Subtotal (95% CI)			**88**			**91**	**83.1%**	**0.78 [0.47, 1.10]**							
Heterogeneity: Tau² = 0.00; Chi² = 8.26, df = 9 (P = 0.51); I² = 0%															
Test for overall effect: Z = 4.89 (P < 0.00001)															
1.4.2 Short-duration exercise (<20min)															
Durkalec-Michalski 2021	303.3	80.2	11	368.1	123.7	11	9.8%	-0.60 [-1.46, 0.26]		+	+	+	+	+	+
Lima-Silva 2011	354.4	151.5	6	519.4	218.1	6	7.0%	-0.81 [-2.01, 0.39]	+	+	+	+	+	+	+
Subtotal (95% CI)			**17**			**17**	**16.9%**	**-0.67 [-1.37, 0.03]**							
Heterogeneity: Tau² = 0.00; Chi² = 0.08, df = 1 (P = 0.78); I² = 0%															
Test for overall effect: Z = 1.88 (P = 0.06)															
Total (95% CI)			**105**			**108**	**100.0%**	**0.58 [0.17, 0.99]**							
Heterogeneity: Tau² = 0.26; Chi² = 22.18, df = 11 (P = 0.02); I² = 50%															
Test for overall effect: Z = 2.75 (P = 0.006)															
Test for subgroup differences: Chi² = 13.84, df = 1 (P = 0.0002), I² = 92.8%															



E. Cortisol, 1 hr post-exercise (all studies: long-duration exercise only).

	LC diet			HC diet				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Shaw 2021	132	176	8	-20	153	8	18.0%	0.87 [-0.17, 1.91]
Terink 2021	516.8	225.2478	14	418.2	239.8402	14	28.8%	0.41 [-0.34, 1.16]
Burke 2021	11.45	5.66	7	-0.03	3.87	6	10.0%	2.17 [0.69, 3.65]
Bishop 2001	714	277	12	491	113	12	23.9%	1.02 [0.16, 1.88]
Langfort 1996	241.19	102.785	8	183.99	174.4008	8	19.3%	0.38 [-0.61, 1.37]
Total (95% CI)			**49**			**48**	**100.0%**	**0.81 [0.31, 1.31]**

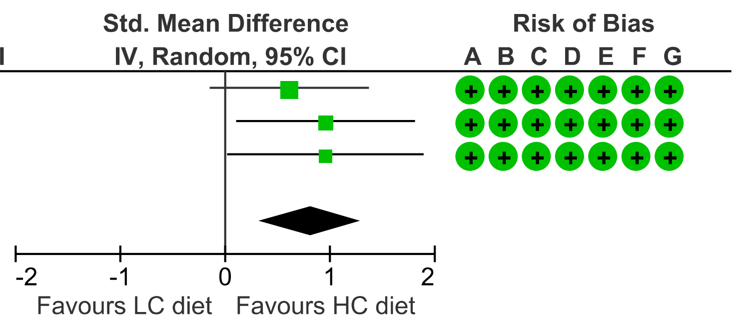
Heterogeneity: Tau² = 0.08; Chi² = 5.27, df = 4 (P = 0.26); I² = 24%
Test for overall effect: Z = 3.18 (P = 0.001)



F. Cortisol, 2 hr post-exercise (all studies: short-term, MP-LC diets & long-duration exercise only).

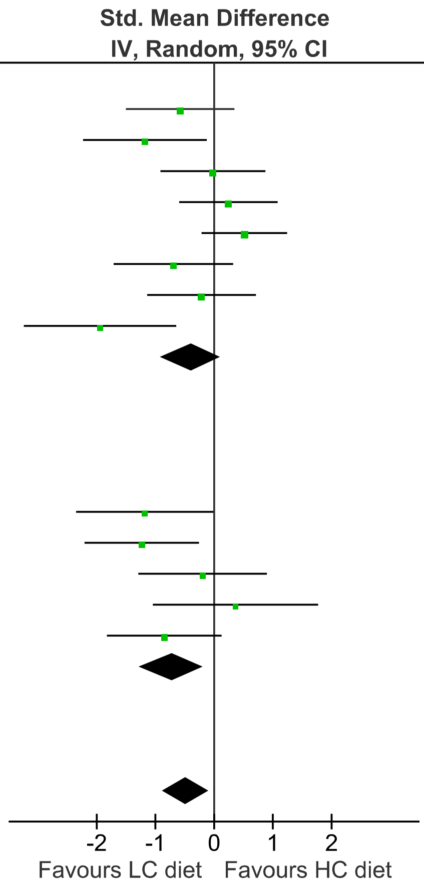
	LC diet			HC diet				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Terink 2021	449.5	231.2344	14	301.7	237.2211	14	40.8%	0.61 [-0.15, 1.37]
Bishop 2001	568	308	12	341	98	12	32.4%	0.96 [0.11, 1.81]
Mitchell 1998	442.1	94.23587	10	348.9	92.33851	10	26.9%	0.96 [0.02, 1.89]
Total (95% CI)			**36**			**36**	**100.0%**	**0.82 [0.33, 1.30]**

Heterogeneity: Tau² = 0.00; Chi² = 0.47, df = 2 (P = 0.79); I² = 0%
Test for overall effect: Z = 3.30 (P = 0.0010)



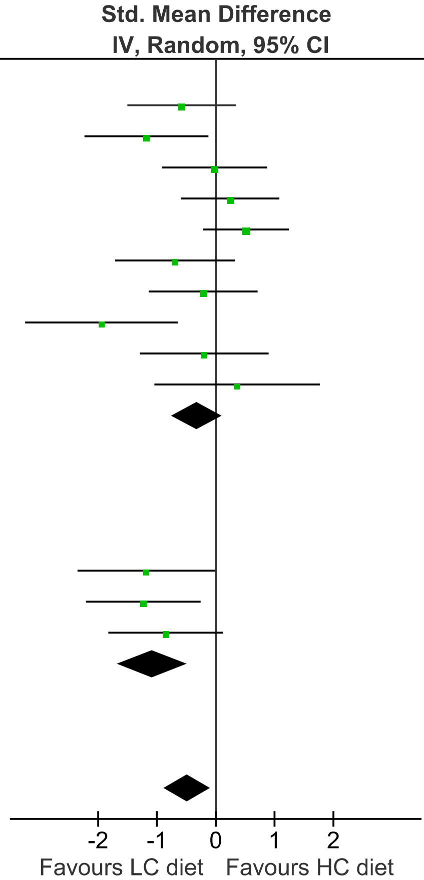
G. Total testosterone, resting, long- vs short-term LC diets.

	LC diet			HC diet				Std. Mean Difference	Risk of Bias						
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
2.1.1 Long-term LC diets (≥3 weeks)															
Paoli 2021	-2.44	4.09	9	0.31	4.91	10	8.4%	-0.58 [-1.50, 0.35]	+		+	+	+	+	+
Toma 2009	-3.72	3.52	8	0.51	3.31	9	7.3%	-1.18 [-2.23, -0.12]	+		+	+	+	+	+
Volek 2002	-0.4	10.1	12	-0.2	6.9	8	8.6%	-0.02 [-0.92, 0.87]			+	+	+	+	−
Durkalec-Michalski 2021	5.84	0.88	11	5.59	1.09	11	9.1%	0.24 [-0.60, 1.08]		+	+	+	+	+	+
Michalczyk 2019	642.37	194.47	15	546.67	167.16	15	10.2%	0.51 [-0.22, 1.24]		+	+	+	+	+	?
Zajac 2014	5.86	0.3	8	6.12	0.4	8	7.6%	-0.70 [-1.71, 0.32]	+	+	+	+	+	+	+
Krings 2021	5.48	2.08	9	5.93	1.89	9	8.4%	-0.22 [-1.14, 0.71]		+	+	+	+	+	?
Burke 2020	-6.73286	3.580204	7	0.311111	3.255133	8	5.7%	-1.94 [-3.24, -0.65]		?	+	+	+	+	+
Subtotal (95% CI)			**79**			**78**	**65.4%**	**-0.39 [-0.90, 0.13]**							
Heterogeneity: Tau² = 0.31; Chi² = 16.52, df = 7 (P = 0.02); I² = 58%															
Test for overall effect: Z = 1.48 (P = 0.14)															
2.1.2 Short-term LC diets (<3 weeks)															
Anderson 1987	371	60.85228	7	468	89.95554	7	6.5%	-1.18 [-2.35, -0.01]		+	+	+	+	+	+
Jaffe 2018	-2.35	3.45	10	1.82	3.01	10	8.0%	-1.23 [-2.21, -0.26]	+	+	+	+	+	+	+
Burke 2021	-2.6	4.8	7	-1.7	3.5	6	7.0%	-0.20 [-1.29, 0.90]			+	+	+	+	+
Tsai 1993	25.7	5.8	4	23.4	5.2	4	5.2%	0.36 [-1.05, 1.77]		+	+	+	+	+	+
Langfort 2001	18.73	3.27	9	22.17	4.35	9	7.9%	-0.85 [-1.83, 0.12]		+	+	+	+	+	+
Subtotal (95% CI)			**37**			**36**	**34.6%**	**-0.71 [-1.26, -0.17]**							
Heterogeneity: Tau² = 0.07; Chi² = 4.89, df = 4 (P = 0.30); I² = 18%															
Test for overall effect: Z = 2.56 (P = 0.01)															
Total (95% CI)			**116**			**114**	**100.0%**	**-0.48 [-0.87, -0.09]**							
Heterogeneity: Tau² = 0.25; Chi² = 23.72, df = 12 (P = 0.02); I² = 49%															
Test for overall effect: Z = 2.43 (P = 0.01)															
Test for subgroup differences: Chi² = 0.74, df = 1 (P = 0.39), I² = 0%															



H. Total testosterone, resting, MP- vs HP-LC diets.

Study or Subgroup	LC diet Mean	LC diet SD	LC diet Total	HC diet Mean	HC diet SD	HC diet Total	Weight	Std. Mean Difference IV, Random, 95% CI	A	B	C	D	E	F	G
2.2.1 MP-LC diets (<35%)															
Paoli 2021	-2.44	4.09	9	0.31	4.91	10	8.4%	-0.58 [-1.50, 0.35]	+		+	+	+	+	+
Toma 2009	-3.72	3.52	8	0.51	3.31	9	7.3%	-1.18 [-2.23, -0.12]	+		+	+	+	+	+
Volek 2002	-0.4	10.1	12	-0.2	6.9	8	8.6%	-0.02 [-0.92, 0.87]			+	+	+	+	−
Durkalec-Michalski 2021	5.84	0.88	11	5.59	1.09	11	9.1%	0.24 [-0.60, 1.08]		+	+	+	+	+	+
Michalczyk 2019	642.37	194.47	15	546.67	167.16	15	10.2%	0.51 [-0.22, 1.24]		+	+	+	+	+	?
Zajac 2014	5.86	0.3	8	6.12	0.4	8	7.6%	-0.70 [-1.71, 0.32]	+	+	+	+	+	+	+
Krings 2021	5.48	2.08	9	5.93	1.89	9	8.4%	-0.22 [-1.14, 0.71]		+	+	+	+	+	?
Burke 2020	-6.73286	3.580204	7	0.311111	3.255133	8	5.7%	-1.94 [-3.24, -0.65]		?	+	+	+	+	+
Burke 2021	-2.6	4.8	7	-1.7	3.5	6	7.0%	-0.20 [-1.29, 0.90]			+	+	+	+	+
Tsai 1993	25.7	5.8	4	23.4	5.2	4	5.2%	0.36 [-1.05, 1.77]		+	+	+	+	+	+
Subtotal (95% CI)			**90**			**88**	**77.6%**	**-0.31 [-0.74, 0.13]**							
Heterogeneity: Tau² = 0.23; Chi² = 17.26, df = 9 (P = 0.04); I² = 48%															
Test for overall effect: Z = 1.39 (P = 0.17)															
2.2.2 HP-LC diets (≥35%)															
Anderson 1987	371	60.85228	7	468	89.95554	7	6.5%	-1.18 [-2.35, -0.01]		+	+	+	+	+	+
Jaffe 2018	-2.35	3.45	10	1.82	3.01	10	8.0%	-1.23 [-2.21, -0.26]	+	+	+	+	+	+	+
Langfort 2001	18.73	3.27	9	22.17	4.35	9	7.9%	-0.85 [-1.83, 0.12]		+	+	+	+	+	+
Subtotal (95% CI)			**26**			**26**	**22.4%**	**-1.08 [-1.67, -0.48]**							
Heterogeneity: Tau² = 0.00; Chi² = 0.34, df = 2 (P = 0.85); I² = 0%															
Test for overall effect: Z = 3.56 (P = 0.0004)															
Total (95% CI)			**116**			**114**	**100.0%**	**-0.48 [-0.87, -0.09]**							
Heterogeneity: Tau² = 0.25; Chi² = 23.72, df = 12 (P = 0.02); I² = 49%															
Test for overall effect: Z = 2.43 (P = 0.01)															
Test for subgroup differences: Chi² = 4.25, df = 1 (P = 0.04), I² = 76.5%															



I. Total testosterone, 0 hr post-exercise, long- vs short-term LC diets.

Study or Subgroup	LC diet Mean	LC diet SD	LC diet Total	HC diet Mean	HC diet SD	HC diet Total	Weight	Std. Mean Difference IV, Random, 95% CI	Risk of Bias A	B	C	D	E	F	G
4.1.1 Long-term LC diets (≥3 weeks)															
Durkalec-Michalski 2021	6.25	0.67	11	5.9	0.75	11	35.7%	0.47 [-0.38, 1.32]		+	+	+	+	+	+
Zajac 2014	8.14	0.6	8	7.91	0.5	8	32.2%	0.39 [-0.60, 1.39]	+	+	+	+	+	+	+
Subtotal (95% CI)			**19**			**19**	**67.9%**	**0.44 [-0.21, 1.09]**							
Heterogeneity: Tau² = 0.00; Chi² = 0.01, df = 1 (P = 0.90); I² = 0%															
Test for overall effect: Z = 1.34 (P = 0.18)															
4.1.2 Short-term LC diets (<3 weeks)															
Langfort 2001	24.39	4.92	9	29.25	4.26	9	32.1%	-1.01 [-2.00, -0.01]		+	+	+	+	+	+
Subtotal (95% CI)			**9**			**9**	**32.1%**	**-1.01 [-2.00, -0.01]**							
Heterogeneity: Not applicable															
Test for overall effect: Z = 1.98 (P = 0.05)															
Total (95% CI)			**28**			**28**	**100.0%**	**-0.03 [-0.95, 0.89]**							
Heterogeneity: Tau² = 0.43; Chi² = 5.71, df = 2 (P = 0.06); I² = 65%															
Test for overall effect: Z = 0.06 (P = 0.95)															
Test for subgroup differences: Chi² = 5.70, df = 1 (P = 0.02), I² = 82.5%															

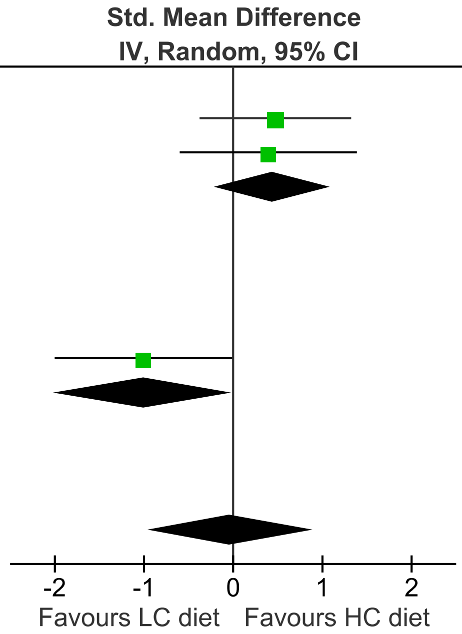
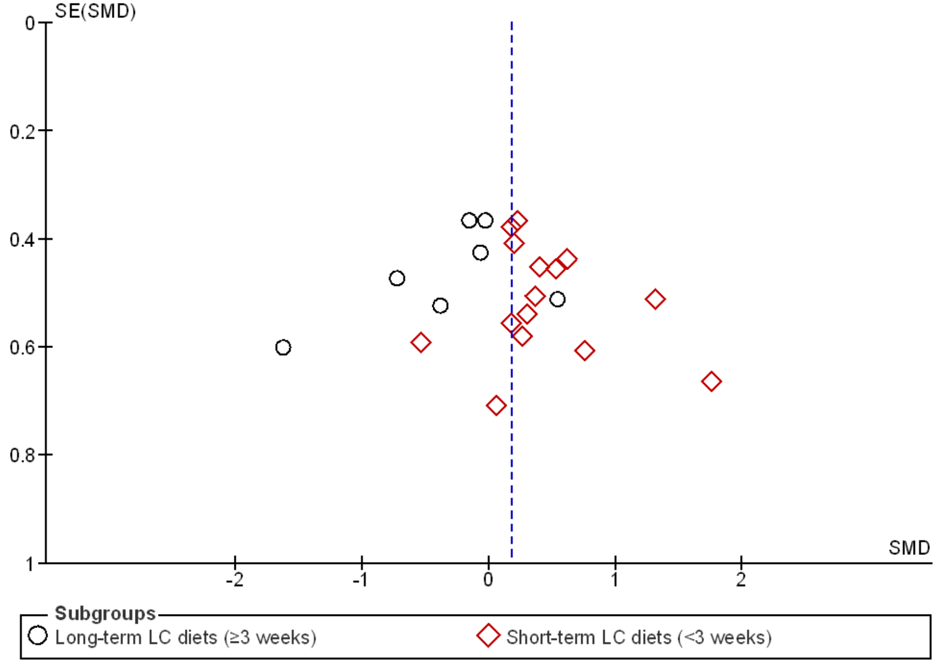
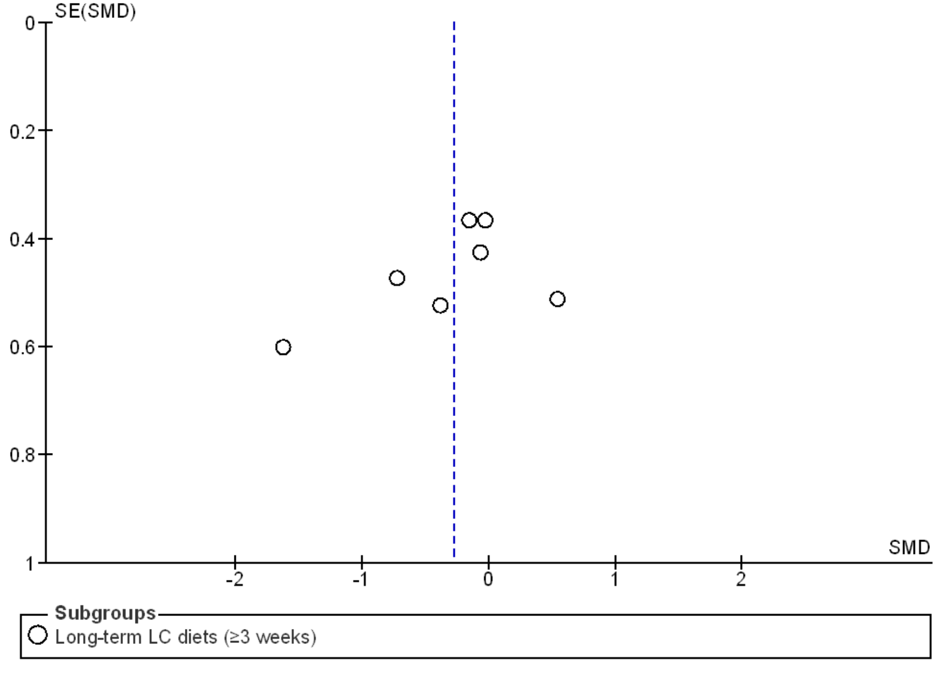


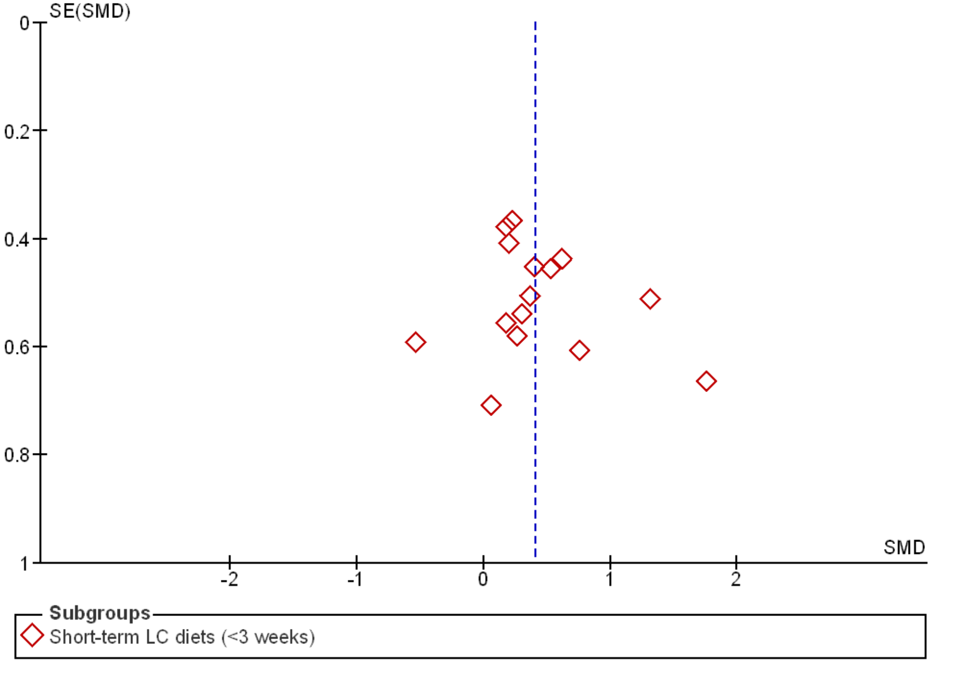
Figure 2. Forest plots with subgroup analyses, showing standardized mean differences of LC vs HC diets. HC: high-carbohydrate; HP: high-protein; LC: low-carbohydrate; MP: moderate-protein.

Risk of bias legend
(A) Bias due to randomization process
(B) Bias due to period and carryover effects
(C) Bias due to deviations from intended interventions
(D) Bias due to missing outcome data
(E) Bias due to measurement of outcome
(F) Bias due to selection of reported result
(G) Bias due to confounding variables

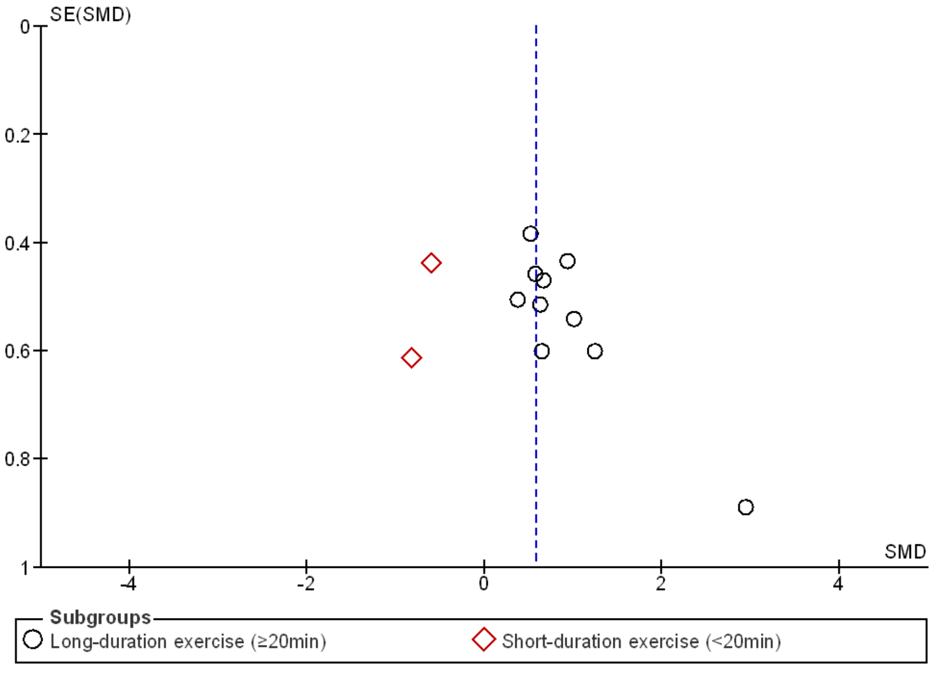
A. Cortisol, resting, long- vs short-term LC diets.

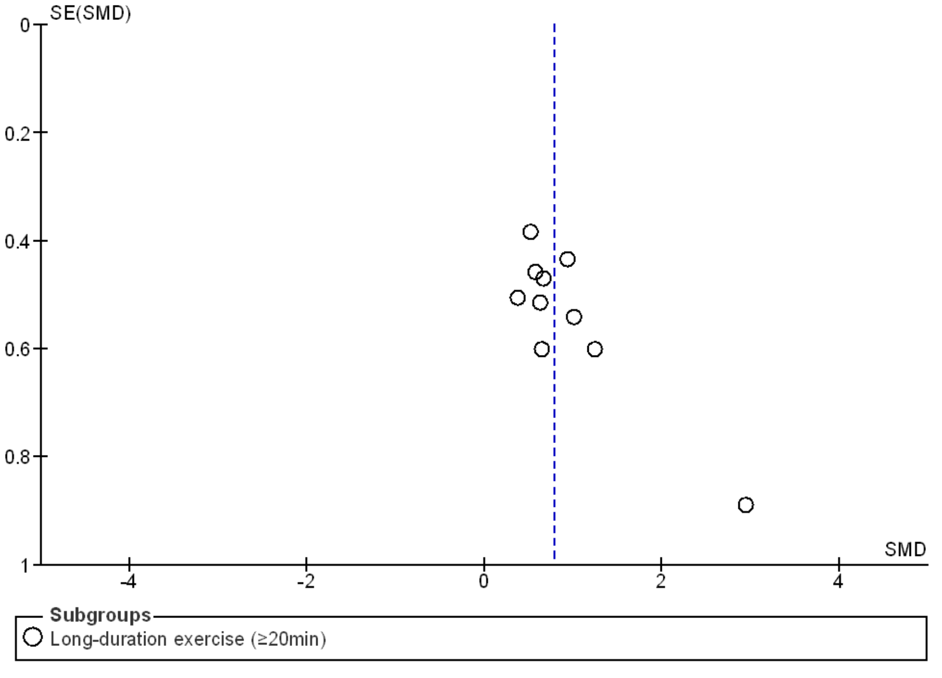


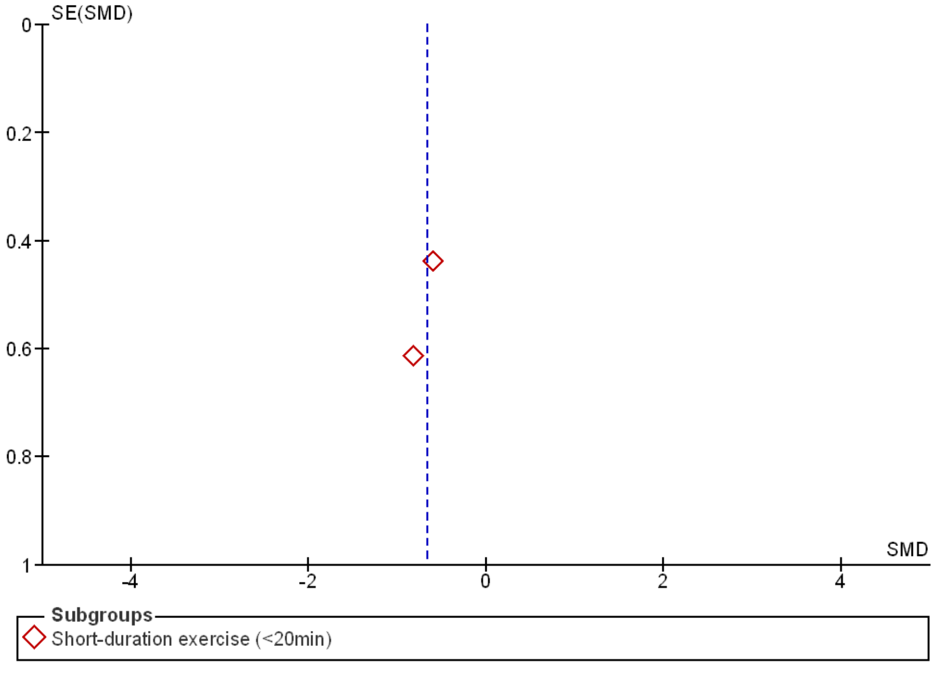




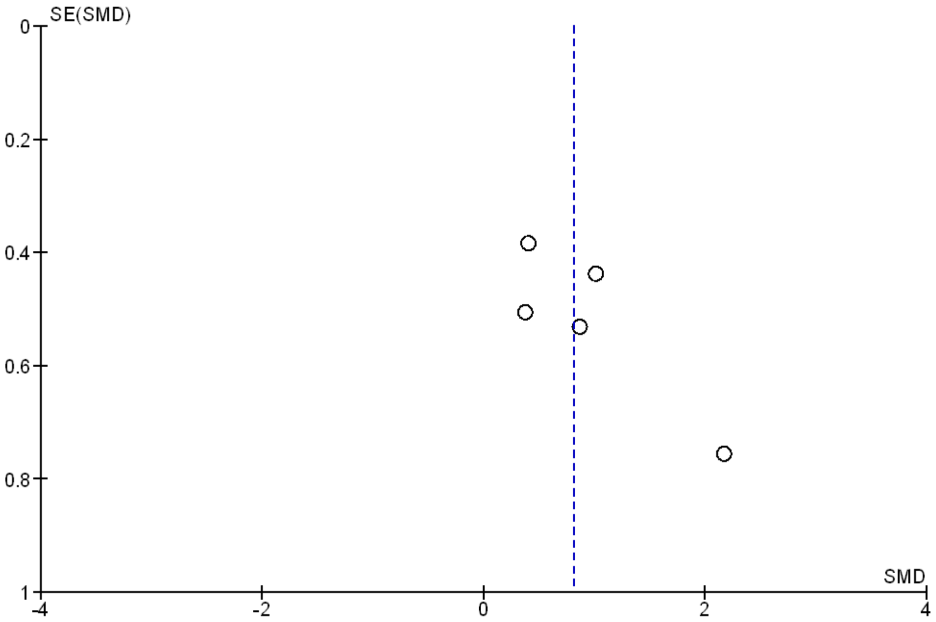
B. Cortisol, 0 hr post-exercise, long- vs short-duration exercise.



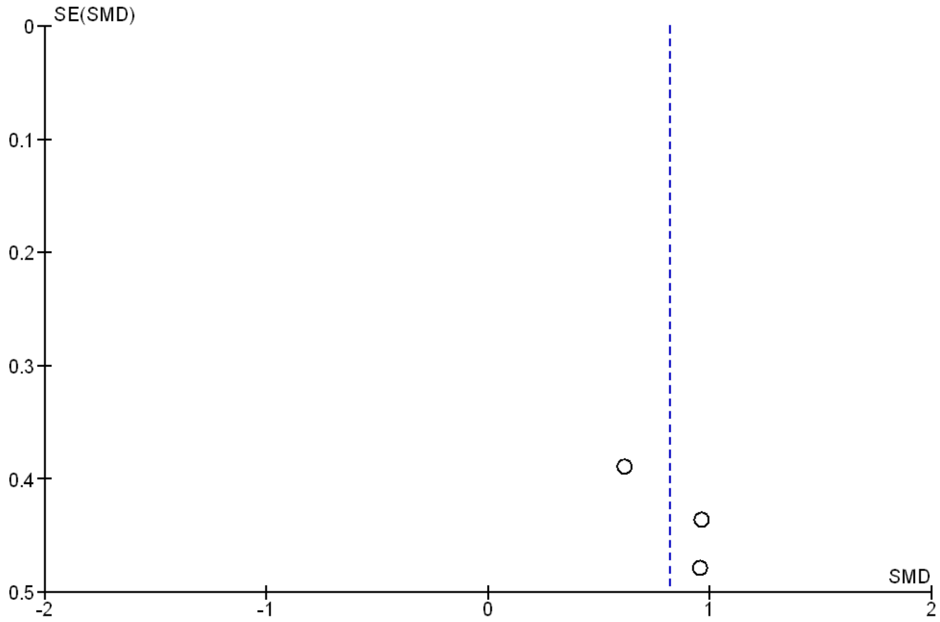




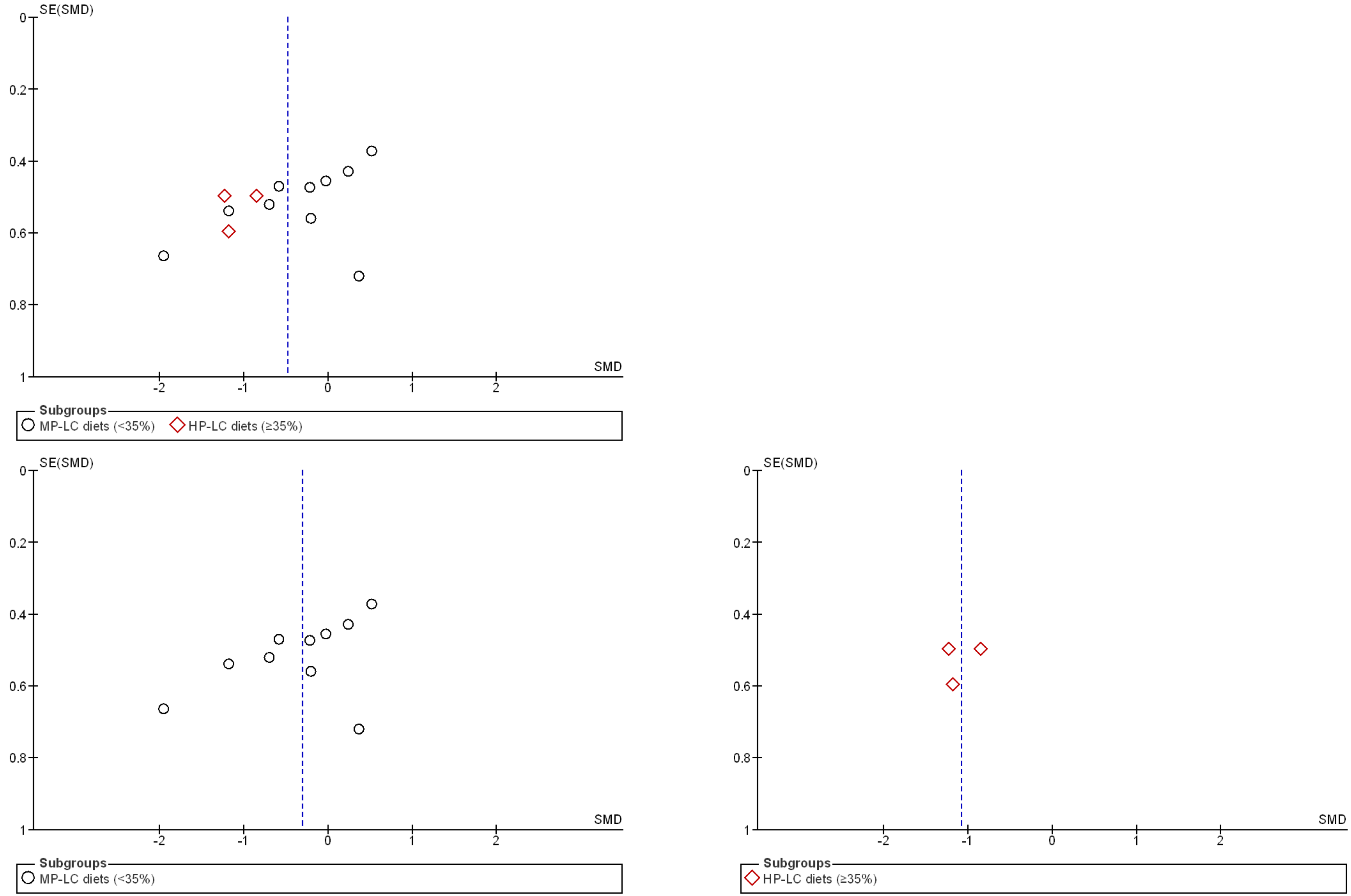
C. Cortisol, 1 hr post-exercise.



D. Cortisol, 2 hr post-exercise.



E. Total testosterone, resting, MP- vs HP-LC diets.



F. Total testosterone, 0 hr post-exercise, long- vs short-term LC diets.

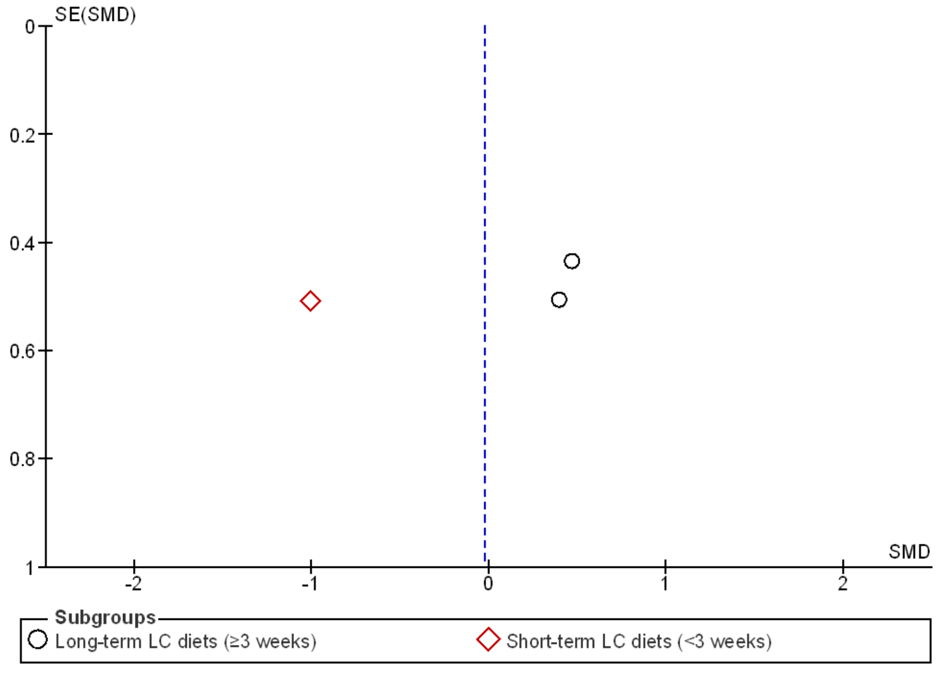
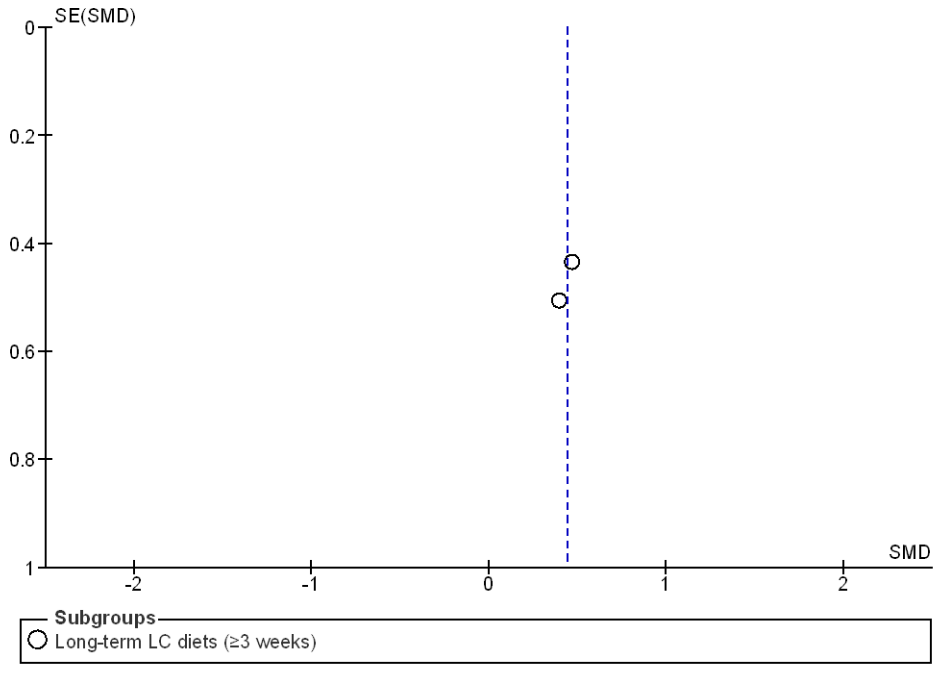


Figure 3. Funnel plots of outcomes, with subgroups that explain heterogeneity. HC: high-carbohydrate; HP: high-protein; LC: low-carbohydrate; MP: moderate-protein; SE: standard error; SMD: standardized mean difference.



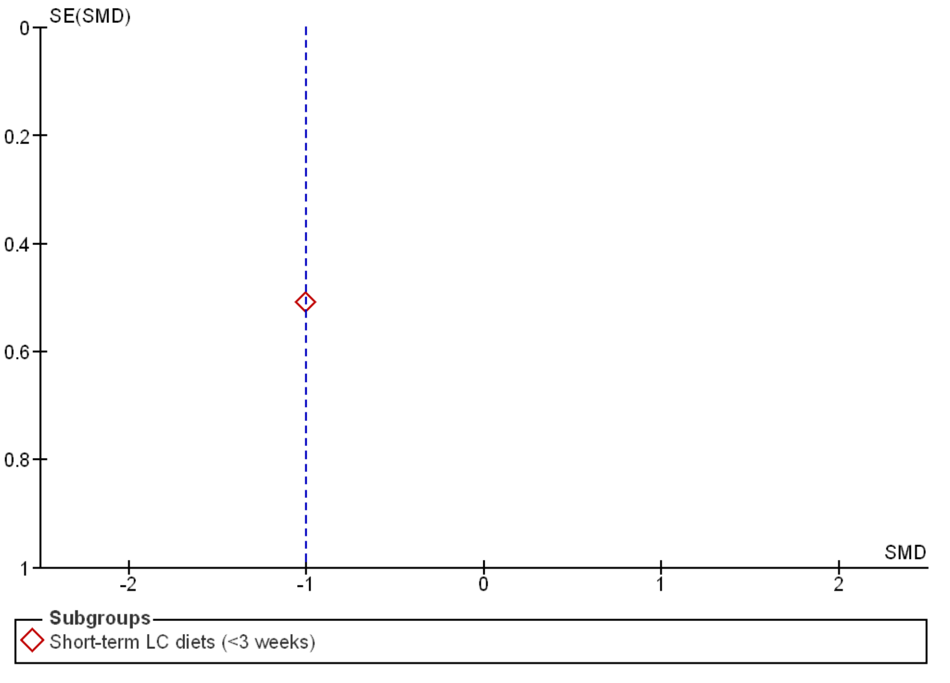


Table 9. Sensitivity analyses.

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
High and medium bias studies excluded						
Cortisol, resting						
All studies	170 (17)	0.34 [0.07, 0.62]	0.01	26	0.15	no
Long-term LC diets	27 (3)	-0.33 [-1.48, 0.81]	0.57	75	0.02	no
Short-term LC diets	143 (14)	0.45 [0.2, 0.71]	<0.01	0	0.76	no
Test for subgroup differences				42.3	0.19	no
Cortisol, 0 hr post-exercise						
All studies	117 (11)	0.58 [0.13, 1.03]	0.01	55	0.01	no
Long-duration exercise	100 (9)	0.79 [0.46, 1.12]	<0.01	3	0.41	no
Short-duration exercise	NA[c]	NA	NA	NA	NA	NA
Test for subgroup differences				92.8	<0.01	no
Cortisol, 1 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Cortisol, 2 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Total testosterone, resting						
All studies	98 (9)	-0.6 [-0.99, -0.21]	<0.01	22	0.25	no
MP-LC diets	72 (6)	-0.36 [-0.82, 0.1]	0.13	17	0.3	no
HP-LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				71.8	0.06	no

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Total testosterone, 0 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Long-term LC diets	NA	NA	NA	NA	NA	NA
Short-term LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				NA	NA	NA
<u>Non-randomized studies excluded</u>						
Cortisol, resting						
All studies	96 (9)	0.22 [-0.27, 0.7]	0.38	54	0.03	no
Long-term LC diets	16 (2)	-0.52 [-2.64, 1.61]	0.64	87	<0.01	no
Short-term LC diets	80 (7)	0.38 [0, 0.76]	0.05	10	0.35	no
Test for subgroup differences				0	0.42	no
Cortisol, 0 hr post-exercise						
All studies	90 (8)	0.56 [0.22, 0.89]	<0.01	0	0.46	yes (reduced heterogeneity)
Long-duration exercise	84 (7)	0.67 [0.32, 1.02]	<0.01	0	0.97	no
Short-duration exercise	6 (1)	-0.81 [-2.01, 0.39]	0.18	NA[d]	NA	no
Test for subgroup differences				81.5	0.02	no
Cortisol, 1 hr post-exercise						
All studies	34 (3)	0.72 [0.22, 1.22]	<0.01	0	0.55	no
Cortisol, 2 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Total testosterone, resting						
All studies	54 (4)	-0.91 [-1.4, -0.41]	<0.01	0	0.72	yes (stronger effect and reduced heterogeneity)
MP-LC diets	44 (3)	-0.79 [-1.37, -0.22]	<0.01	0	0.69	yes (stronger effect, p <0.05, and reduced heterogeneity)
HP-LC diets	10 (1)	-1.23 [-2.21, -0.26]	0.01	NA	NA	no
Test for subgroup differences				0	0.45	yes (no subgroup effect)
Total testosterone, 0 hr post-exercise						
All studies	8 (1)	0.39 [-0.6, 1.39]	0.44	NA	NA	no
Long-term LC diets	8 (1)	0.39 [-0.6, 1.39]	0.44	NA	NA	no
Short-term LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				NA	NA	NA
<u>Studies using carbohydrate supplements during exercise on HC diets excluded</u>						
Cortisol, 0 hr post-exercise						
All studies	98 (9)	0.41 [-0.01, 0.83]	0.06	40	0.1	yes (weaker effect)
Long-duration exercise	81 (7)	0.7 [0.34, 1.06]	<0.01	0	0.94	no
Short-duration exercise	NA	NA	NA	NA	NA	NA
Test for subgroup differences				91.4	<0.01	no
Cortisol, 1 hr post-exercise						
All studies	34 (3)	0.6 [0.11, 1.09]	0.02	0	0.51	yes (weaker effect)
Cortisol, 2 hr post-exercise						
All studies	26 (2)	0.77 [0.2, 1.33]	<0.01	0	0.55	no

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Total testosterone, 0 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Long-term LC diets	NA	NA	NA	NA	NA	NA
Short-term LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				NA	NA	NA
Using alternative HC diets from studies with two eligible HC diets						
Cortisol, resting						
All studies	245 (22)	0.17 [-0.08, 0.42]	0.18	33	0.07	no
Long-term LC diets	NA	NA	NA	NA	NA	NA
Short-term LC diets	155 (15)	0.4 [0.15, 0.65]	<0.01	0	0.56	no
Test for subgroup differences				86.3	<0.01	no
Cortisol, 0 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Long-duration exercise	NA	NA	NA	NA	NA	NA
Short-duration exercise	NA	NA	NA	NA	NA	NA
Test for subgroup differences				NA	NA	NA
Cortisol, 1 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Cortisol, 2 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Total testosterone, resting						
All studies	155 (13)	-0.48 [-0.87, -0.08]	0.02	50	0.02	no
MP-LC diets	129 (10)	-0.3 [-0.74, 0.14]	0.18	49	0.04	no
HP-LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				76.7	0.04	no
Total testosterone, 0 hr post-exercise						
All studies	NA	NA	NA	NA	NA	NA
Long-term LC diets	NA	NA	NA	NA	NA	NA
Short-term LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				NA	NA	NA
<u>One study at a time excluded & analysis rerun</u> (ranges presented)						
Cortisol, resting						
All studies	225 - 241 (21)	0.13 [-0.09, 0.36] - 0.23 [0.02, 0.44]	0.03 - 0.28	7 - 35	0.06 - 0.37	no
Long-term LC diets	70 - 82 (6)	-0.13 [-0.47, 0.22] - -0.37 [-0.79, 0.04]	0.07 – 0.47	0 - 46	0.1 – 0.6	no
Short-term LC diets	135 - 151 (14)	0.35 [0.09, 0.61] - 0.45 [0.2, 0.71]	<0.01 - <0.01	0 - 0	0.55 – 0.88	no
Test for subgroup differences				81 – 90.2	<0.01 - 0.02	no

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Cortisol, 0 hr post-exercise						
All studies	109 – 123 (11)	0.47 [0.12, 0.83] - 0.7 [0.32, 1.07]	<0.01 – 0.02	32 - 55	0.01 - 0.15	no
Long-duration exercise	92 - 105 (9)	0.71 [0.39, 1.03] - 0.84 [0.49, 1.18]	<0.01 - <0.01	0 - 3	0.41 – 0.98	no
Short-duration exercise	6 – 11 (1)	-0.6 [-1.46, 0.26] - -0.81 [-2.01, 0.39]	0.17 - 0.18	NA	NA	no
Test for subgroup differences				84.2 – 93.1	<0.01 – 0.01	no
Cortisol, 1 hr post-exercise						
All studies	41 - 47 (4)	0.65 [0.21, 1.09] - 0.97 [0.37, 1.57]	<0.01 - 0.02	0 - 43	0.16 – 0.67	no
Cortisol, 2 hr post-exercise						
All studies	22 – 26 (2)	0.75 [0.16, 1.34] - 0.96 [0.33, 1.59]	<0.01 – 0.01	0 - 0	0.55 - 1	no
Total testosterone, resting						
All studies	135 - 151 (12)	-0.59 [-0.95, -0.22] - -0.38 [-0.75, -0.02]	<0.01 - 0.04	33 - 53	0.01 – 0.12	no
MP-LC diets	109 – 125 (9)	-0.16 [-0.52, 0.2] - -0.42 [-0.85, 0]	0.05 - 0.4	22 - 54	0.03 – 0.25	no
HP-LC diets	16 – 19 (2)	-0.99 [-1.74, -0.24] - -1.21 [-1.96, -0.46]	<0.01 – 0.01	0 - 0	0.59 – 0.95	no
Test for subgroup differences				58.1 – 85.3	<0.01 - 0.12	no

Sensitivity analysis, outcome & subgroup[a]	Participants (studies)	SMD [95% CI]	P-value (Z test)	I^2 (%)	P-value (Chi^2 test)	Significantly different to original result (yes/no)[b]
Total testosterone, 0 hr post-exercise						
All studies	17 – 20 (2)	-0.31 [-1.68, 1.07] - 0.44 [-0.21, 1.09]	0.18 - 0.74	0 - 80	0.03 – 0.9	no
Long-term LC diets	8 – 11 (1)	0.39 [-0.6, 1.39] - 0.47 [-0.38, 1.32]	0.27 - 0.44	NA	NA	no
Short-term LC diets	NA	NA	NA	NA	NA	NA
Test for subgroup differences				73.7 - 79.6	0.03 – 0.05	no

[a] Long-term (≥3 weeks), short-term (<3 weeks), long-duration exercise (≥20 min), short-duration exercise (<20 min), MP (<35% protein), HP (≥35% protein).
[b] This was a qualitative not quantitative judgement.
[c] NA as the sensitivity analyses were identical to original analyses (i.e. the outcome or subgroup contains no high/ medium bias, non-randomized, carbohydrate supplement, or alternative HC diet studies).
[d] NA for I^2 and Chi^2 tests in subgroups containing only one study.
CI: confidence interval; HC: high-carbohydrate; HP: high-protein; LC: low-carbohydrate; MP: moderate-protein; NA: not applicable; SMD: standardized mean difference.

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