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A systematic review and meta-analysis comparing cardiopulmonary exercise test values obtained from the arm cycle and the leg cycle respectively in healthy adults

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Key words: aerobic capacity, exercise testing, oxygen uptake, leg cycle, arm cycle, ergometer, systematic review, meta-analysis.

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Abstract (200 words)

Introduction: The cardiopulmonary exercise test (CPET) assesses maximal oxygen uptake (VO2max) and is commonly performed on a leg cycle ergometer (LC). However, some individuals will rather perform the CPET on an arm cycle ergometer (AC).

Objective: To compare VO2max values obtained by the AC test and the LC test in healthy adults.

Methods: MEDLINE, EMBASE, CINAHL, and PEDro were searched in April 2015. Studies were included if they reported within comparison VO2max values obtained from CPET using AC and LC in healthy adults. The differences in VO2max ($ACLC_{diff}$) were pooled across studies using random effects meta-analysis and three different methods were used to estimate the ratio between the values obtained from the tests ($ACLC_{ratio}$).

Results: We included 41 studies with a total of 581 participants. The mean $ACLC_{diff}$ across studies was 12.5 ml/kg/min and 0.89 l/min with a mean $ACLC_{ratio}$ of 0.70. The $ACLC_{diff}$ was lower in studies with higher mean age and lower aerobic capacity.

Conclusion: There is linear association between the AC and LC values in healthy non-athletic individuals. The AC obtained values were on average 70% of the LC values. The magnitude of this difference appeared to be reduced in studies on older and less active populations.

1. Introduction

The cardiopulmonary exercise test (CPET) is the gold standard for the direct assessment of maximal oxygen uptake (VO_{2max}) [1-5]. VO_{2max} determines the maximal ability for the human body to deliver, obtain and consume oxygen during maximal exercise and is a measure of maximum aerobic capacity [4]. Assessments of aerobic capacity are used by physicians and healthcare professionals to evaluate exercise capacity [5], exercise intolerance [6] and functional aerobic impairment [7], which all provide important information on health status and prognosis in various populations [2,8-11].

CPET is commonly performed on a treadmill or on a leg cycle ergometer (LC) [3,5]. However, due to disability, co-morbidity, preference or athletic discipline there is a need to investigate alternatives to LC [12]. In some cases, it could be more important to assess arm fitness when leg exercise is not feasible or possible [13-15]. A potential alternative is to perform the test with the upper body using an arm cycle ergometer (AC)[13]. The AC test is however challenged as studies have shown that untrained individuals will achieve a lower level of VO_{2max} on the AC, due to a reduced stress on the cardiovascular system, compared to LC [12,15,16]. Having a smaller amount of muscle mass being active during the test, AC is likely to result in an earlier termination of the CPET due to peripheral factors such as an earlier onset of lactate threshold, rather than central cardiovascular limitations [12,17]. Whilst individual studies have directly assessed the difference in $VO2_{max}$ of a CPET conducted using AC compared to LC in healthy adults, we know of no previous systematic review of these studies.

The objectives of this study were to undertake a systematic review and meta-analysis of the VO_{2max} achieved by AC compared to LC in healthy adults and to explore factors that may be predictive of this difference. The determination of this factor would allow the direct comparison of data obtained on the two tests.

2. Methods

This review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [18].

2.1 Data sources and searches

Preliminary searches were conducted and relevant search terms identified. A formal search of the databases MEDLINE, EMBASE, CINAHL, and PEDro was undertaken in April 2015. References of the identified studies in the preliminary searches were screened and relevant search terms were added to the search strategy. The search strategy consisted of a combination of relevant keywords and MeSH/Thesaurus terms for: 1) direct assessment of $VO2_{max,}$ 2) a CPET performed on an AC and 3) a CPET performed on an LC. No language or publication limits were applied. The reference lists of identified studies were checked and we contacted the authors of unobtainable studies and evaluated papers suggested by experts in the field. Search strategies specified for MEDLINE is presented in appendix.

2.3 Study selection

Study selection was undertaken based on a priori defined criteria. Only original research papers reporting within comparison maximum or peak VO_2, as litres per minute (l/min) or as millilitre oxygen per kilogram per minute (ml/min/kg), were considered eligible for inclusion in this systematic review. The CPET had to be non-assisted on AC and LC. We included studies in groups of healthy adults (age >18 years) with a reported level of physical activity < 300 minutes per week. People with higher physical activity levels were considered athletes and where therefore excluded [19].

Two authors (RTL, CK) independently screened titles and abstracts and assessed eligible articles in full-text. Any inconsistencies between authors were discussed and disagreement was solved by consultation of a third author (JC).

2.4 Data extraction and risk of bias assessment

The following information was extracted: sample size, gender distribution, mean age, mean height, body mass index (BMI) together with the $VO2_{max}$ values, peak respiratory exchange ratio (RER), CPET starting Watt, and Watt increment for both the AC and LC test.

The Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [20] was used to assess the methodological quality of all included studies. Six items (6-10 and 13) were considered not applicable for the studies included in this review and thus did not contribute to the quality rating total score (SumQAT). Two authors (RTL and CK) independently extracted data and undertook the quality assessment. Inconsistencies between reviewers were discussed and in cases of disagreement, a third reviewer (JC) was consulted.

2.5 Data analysis

The mean $VO2_{max}$ difference between AC and LC ($ACLC_{diff}$) was calculated for each study. Given the within subject nature of these comparisons we adjusted the standard deviation of this difference for the within subject correlation using the method described in chapter 16.4.6.1 of the Cochrane Handbook [21]. The level of statistical heterogeneity was assessed using the I^2 score. The $ACLC_{diff}$, for ml/kg/min and l/min, were pooled across studies using a conservative random effects meta-analysis given the variation participant characteristics across included studies. Summary of the characteristics of included studies are expressed as median values and interquartile range (IQR).

We used meta-regressions to perform sub-group analyses to clarify, which variables were affecting the main analysis on the $ACLC_{diff.}$ The sub-groups included were: aerobic capacity (as a categorical variable based the Aastrand classification -"low", "fair", "average", "good" or "high")[22], participant mean age (in years), participant gender (percentage of males), study risk of bias (SumQAT), and the difference in peak RER values during test.

Three different approaches were used to find the ratio between AC and LC ($ACLC_{ratio}$). First a meta-analysis of the $ACLC_{ratio}$ was undertaken using the studies presenting the group mean ± standard deviation of the within comparison ratio (%). Second a linear regression model was determined using the group mean values. The linear regression analysis was weighted by sample size. Third the reported AC values were divided with the reported LC values, giving an estimate of the ratio in each study, which are expressed as a total mean ratio.

All analyses were performed using Review Manager 5.3 (Cochrane collaboration) software and Stata 14.0 software (StataCorp. 2013. *Stata Statistical Software: Release 14.9* College Station, TX: StataCorp LP). A p-value ≤ 0.05 was considered statistically significant.

3. Results

3.1 Study selection

Our database searches identified 3,300 records. After removing 617 duplicates, 2,683 unique studies remained. We excluded 2,510 studies by screening their title and abstract and 173 studies were considered eligible for full text review. Of these, 131 did not meet the inclusion criteria. Thus, 41 studies (published between 1973 and 2014) were included in the review [12,15,17,23-60]. Citations and reasons for full text exclusion are listed in appendix. The study selection process is summarised as a flow chart in Figure 1.

3.2 Description of studies

A summary of the characteristics of the included studies is provided in Table 1. The full characteristics of included studies are listed in appendix.

3.3 Risk of bias in included studies

Figure 2 presents a summary of the risk of bias in the included studies. The median SumQAT was 4 points, (IQR: 3 to 5). A detailed risk of bias of each study is listed in appendix.

3.3.1 Research question and study population

Although all included studies were judged to have a well-defined research question (item 1), 13 groups [15,17,25,30,34-38,44,47,52,53] had insufficient description of the study population (item 2). One study [43] described the participation rate of eligible subjects (item 3) and 13 [15,24,26,29,32,33,35,36,41,43,46,55,57] studies had a subject-recruitment within the same population (item 4). Four studies [15,38,39,46] included sample size justification (item 5).

3.3.2 Outcome measures

Five studies [17,34,40,45,53] did not report the $VO2_{max}$ as ml/kg/min but as l/min (item 11) and therefore not adjusting their outcome for subject weight.

3.3.3 Blinding and statistical analysis

One study [12] blinded the outcome assessor (item 12) and 12 studies [25,34,37,38,40,42,43,45,48,51,52,55] did not provide report a description of their statistical analysis methods (item 14).

3.4 Meta-analysis of $VO2_{max}$difference between AC and LC

A total of 36 groups (413 participants) reported data on the $ACLC_{diff}$ measured in ml/kg/min. The meta-analysis for the $ACLC_{diff}$ is shown in Figure 3. The pooled mean VO_{2max} was 12.5 ml/kg/min, (95% CI: 10.3 to 14.7, I^2 = 59.9%, p > 0.001) higher for LC than AC. A total of 37 comparisons (415 participants) presented data of the $ACLC_{diff}$ in l/min with pooled mean VO_{2max} of 0.89 l/min, (95% CI: 0.78 to 1.00, I^2 = 30.5%, p=0.043) higher for LC than AC as shown in figure 4.

3.5 Subgroup analyses

In univariable meta-regression and multivariable meta-regression, lower participant mean age and higher aerobic capacity were found to be significantly associated an increased $ACLC_{diff}$. The meta-regressions are shown in Table 2.

3.6 Analyses of the AC/LC ratio

The mean ratio between the AC and LC for the 37 groups (n=413 participants) reporting $VO2_{max}$ in ml/kg/min was 0.70 (95% CI: 0.66 to 0.73) in favour of the LC. The corresponding value of the 37 groups (n=415 participants) reporting VO_{2max} in l/min, the mean $ACLC_{ratio}$ was 0.71 (95% CI: 0.66 to 0.75). The meta-analysis (n=46 studies) for the $ACLC_{ratio}$ across studies as 71%, (95% CI: 68 to 74, I^2 = 0%, p=0.530) (Figure 5). The coefficient for the linear regression between AC and LC mean VO2max was 0.65 ml/kg/min (95% CI: 0.48 to 0.81) with an r^2 of 0.689 (Figure 6).

4. Discussion

This systematic review and meta-analysis brings together data from 41 studies in 581 healthy individuals directly comparing VO_{2max} values obtained from the AC compared to LC. We found the LC to have substantively higher VO_{2max} value (mean difference: 12.5 ml/kg/min and 0.89 l/min) than AC. But with an I^2 value of 59.9% for the $ACLC_{diff}$ in ml/kg/min these results could be affected by substantial heterogeneity. Our results support the belief that the AC test achieves lower oxygen uptake values as it involves a smaller amount of muscle mass and places less stress on the cardiovascular system [12,15,16].

Both age and the aerobic capacity appear to be associated with the $ACLC_{diff.}$ The difference is decreased with increasing age and increased with better aerobic capacity. This was somehow expected, due to the fact that aerobic capacity decreases with age [22].

The RER represent the relationship between the volume of carbon dioxide and the volume of oxygen in every breath and it is recommended to continue VO_{2max} tests until RER values above 1.1 are reached in order to obtain a valid CPET [23]. The majority of studies reporting RER values reported values in both tests to be above 1.1 [23,24,26-29,32,36,38,46,60]. Only one study reported RER values for the AC to be above 1.1 and RER values for the LC to be below 1.1 [23], and three studies reported RER for both test to be below 1.1 [33,39,49]. We expected the difference in the obtained RER values to affect the $ACLC_{diff}$. However, we did not find this relationship, which could be due to by a lack of power, as only 24 and 16 studies are included in the meta-regressions. The level of aerobic capacity is somehow affected by gender [22]. However, we did not find a correlation between gender distribution and the $ACLC_{diff}$. This makes our results applicable for future research and clinical use in single gender groups as well as mixed gender groups.

The $ACLC_{diff}$ does not seem to be affected by the risk of bias in the studies as low quality studies are reporting the same $ACLC_{diff}$ as high quality studies. This may be explained by the precise and accurate equipment used in CPET [61], and thereby the possibility of precise testing in different settings, which increases the clinical applicability.

The most accurate estimate of the ratio is the meta-analysis of the reported ratios, but only four studies [33,39,46,54] reported mean ± SD (%) values for the ratio between the tests. The meta-analysis revealed a linear relationship between the AC values and LC values with an $ACLC_{ratio}$ of 70%. This analysis should be seen as the main expression for the ratio between the values of the AC and the LC, where no important heterogeneity were found [62]. Three different methods were used to estimate the $ACLC_{ratio}$ due to the number of studies reporting values to incorporate in the meta-analysis for the ratio. The calculation and the linear regression of the $ACLC_{ratio}$ should only be used as a prediction, since they do not incorporate standard deviations. Despite different approaches to estimate the ratio, the results are very similar and the $ACLC_{ratio}$ of 70% is similar to the ones described in the literature [33,39,46,54]. To increase the power of this and investigate if the 70% is a valid estimate for the population mean $ACLC_{ratio}$, future research should report within comparison ratios between the AC and the LC, making them applicable for inclusion in meta-analysis.

This is the first systematic review and meta-analysis of literature comparing arm and leg exercise, and it is thus important to stress that our study has a number of limitations. First, some studies did not report $ACLC_{diff}$ standard deviation which meant we had to impute the value based on an assumed within participant correlation coefficient (r-value) between AC and LC $VO2_{max}$. This method is recommended by the Cochrane Handbook [21] but we acknowledge that it may influence the accuracy of our findings. The only way to avoid these limitations in a meta-analysis is for future research to report the correlation coefficients between the two tests. However, we undertook sensitivity analyses to assess the impact of this estimation on our findings. A small number of studies have reported a range of correlation coefficients between the AC test and the LC test (0.78, 0.94, 0.77, 0.32, 0.70) [12,17,31,37,54]. The pooled $ACLC_{diff}$ was found to be 12.52 ml/kg/min (95% CI: 10.2 to 14.6) based on the lowest of these r-values (0.32) and 12.6 ml/kg/min (95% CI: 10.6 to 14.7) with the highest reported r-value (0.94). In other words, this imputation method made little or no difference to the pooled results. Future studies need to report the standard deviation (or equivalent) of the mean difference between AC ad LC VO_{2max} or the within person correlation coefficient.

Secondly, the quality of the included studies was variable. In this review, we sought to assess study risk of bias using the QAT, tool as it can be applied to cross-sectional studies [20]. However, to make this tool relevant to this review we had to adapt it by dropping some of the original QAT elements (items 6-10 and item 13)

Thirdly, this review was limited to non-athlete healthy adults and limits generalizability of our findings. Non-athlete healthy adults are expected to have a larger aerobic capacity when doing CPET using the legs compared to the arms due to everyday use and large lower limb muscle mass [29]. However, in athletic populations, particularly arm-trained populations, the $ACLC_{diff}$ is expected to be smaller than shown in this review [63]. To avoid systematic bias we excluded 18 comparisons in individuals performing more than 300 minutes per week of physical activity or involved in competitive exercise [19]. The groups contained ‘well trained subjects’, ‘triathletes’, ‘swimmers’, ‘cross-country skiers’ or ‘highly arm-trained’. However, we did not exclude studies in sedentary individuals. Two of the studies included extremely sedentary or sedentary subjects [39,47]. But having an $ACLC_{ratio}$ of 76% and 64% these studies are not likely to have had a systematic affect on our results. A sensitivity analysis was performed without the two studies and showed only minor impact on the result. The pooled $ACLC_{diff}$ was found to be 12.7 ml/kg/min (95% CI: 10.4 to 15.0). Future well conducted studies are needed that directly compare AC and LC in other populations, especially in disease populations with limitations by lower limb disability such as peripheral vascular disease or osteoarthritis.

5. Conclusion

This systematic review and meta-analysis showed that in studies on healthy non-athletic individuals although there was a linear association between the VO_{2max} for AC and LC tests, the VO_{2max} achieved by AC tests were on average 70% lower than compared to the LC. This magnitude of this difference appeared to be reduced in studies with older and less active populations.

6. Conflicts of interest

All authors declare that they have no conflict of interest.

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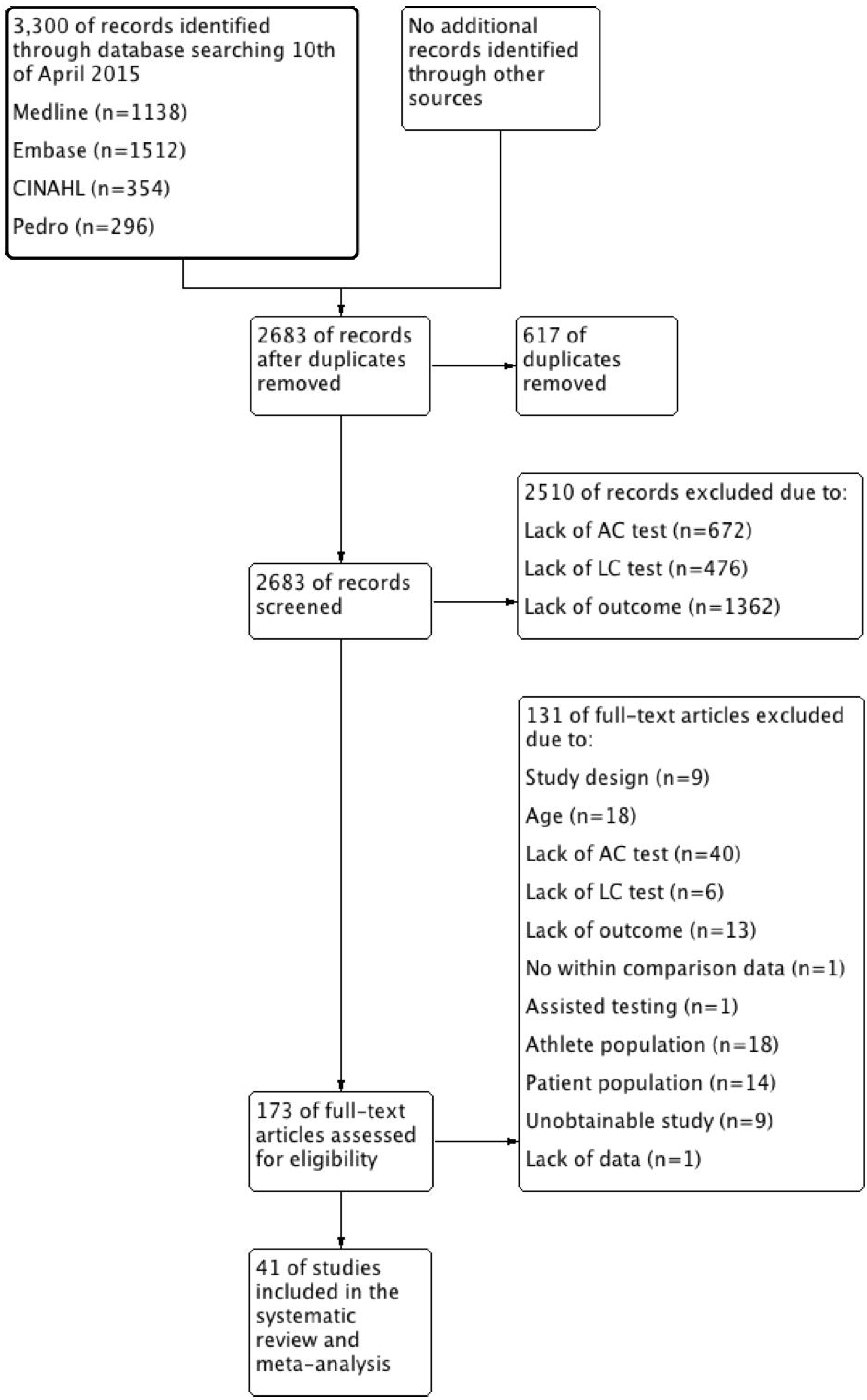
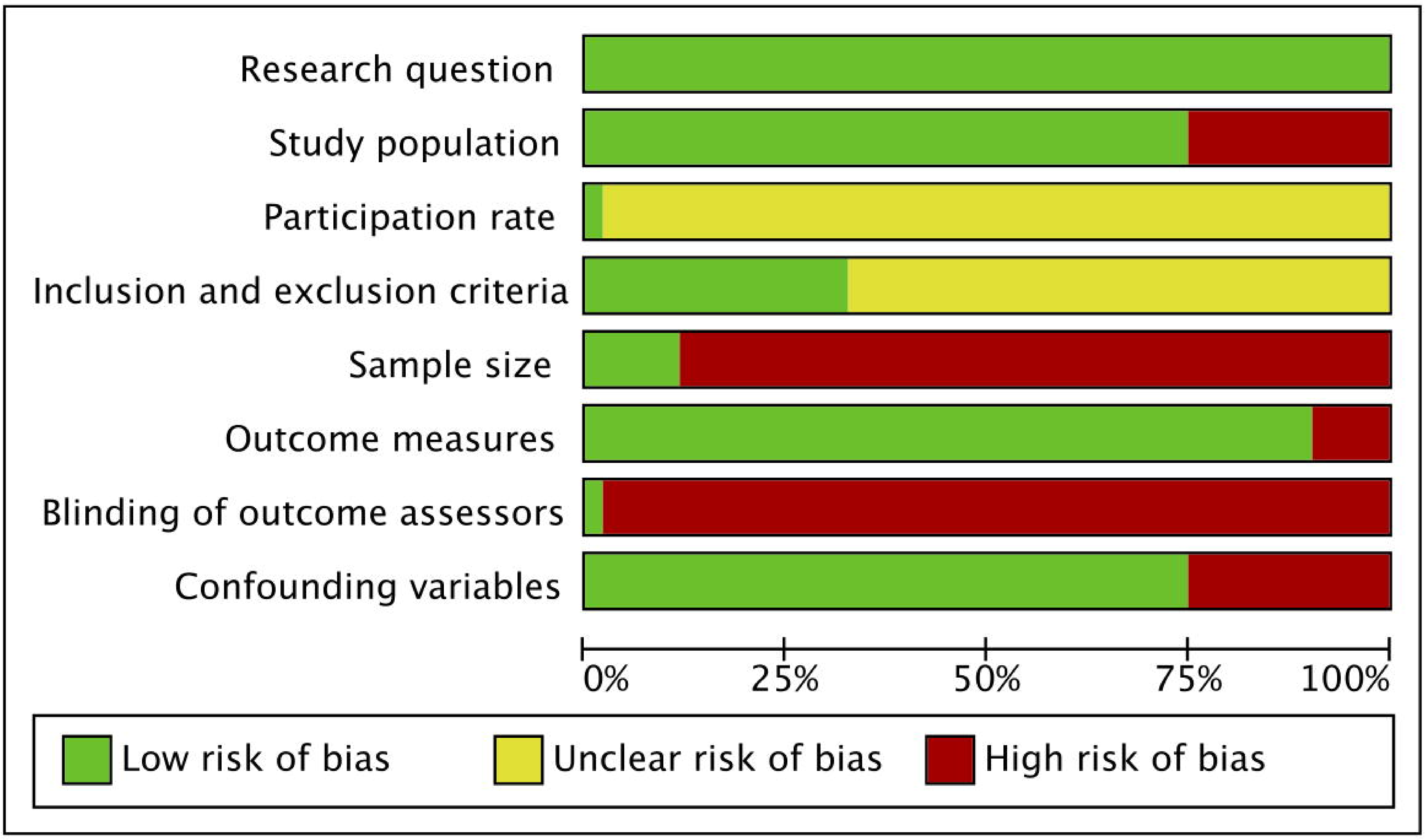
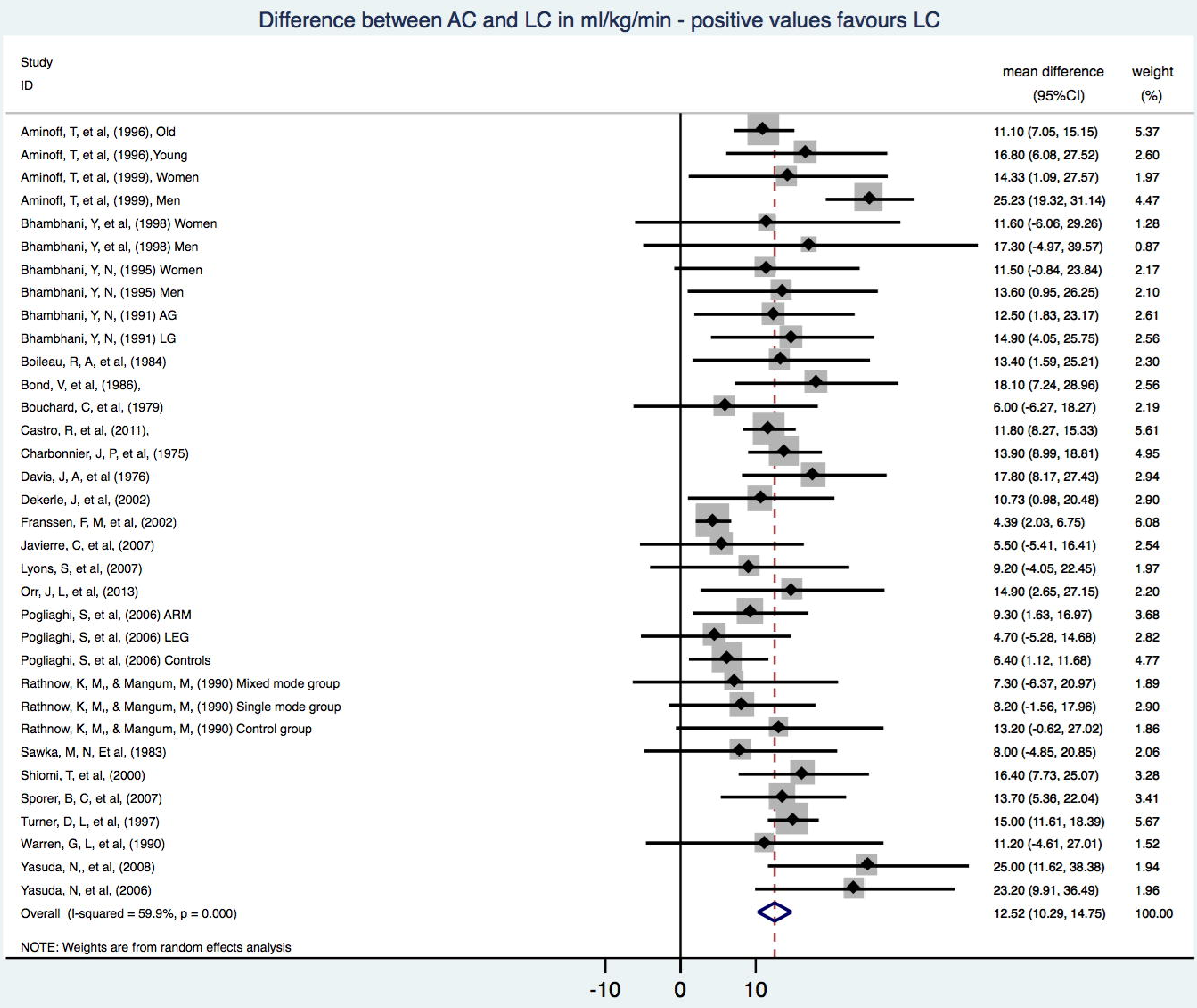
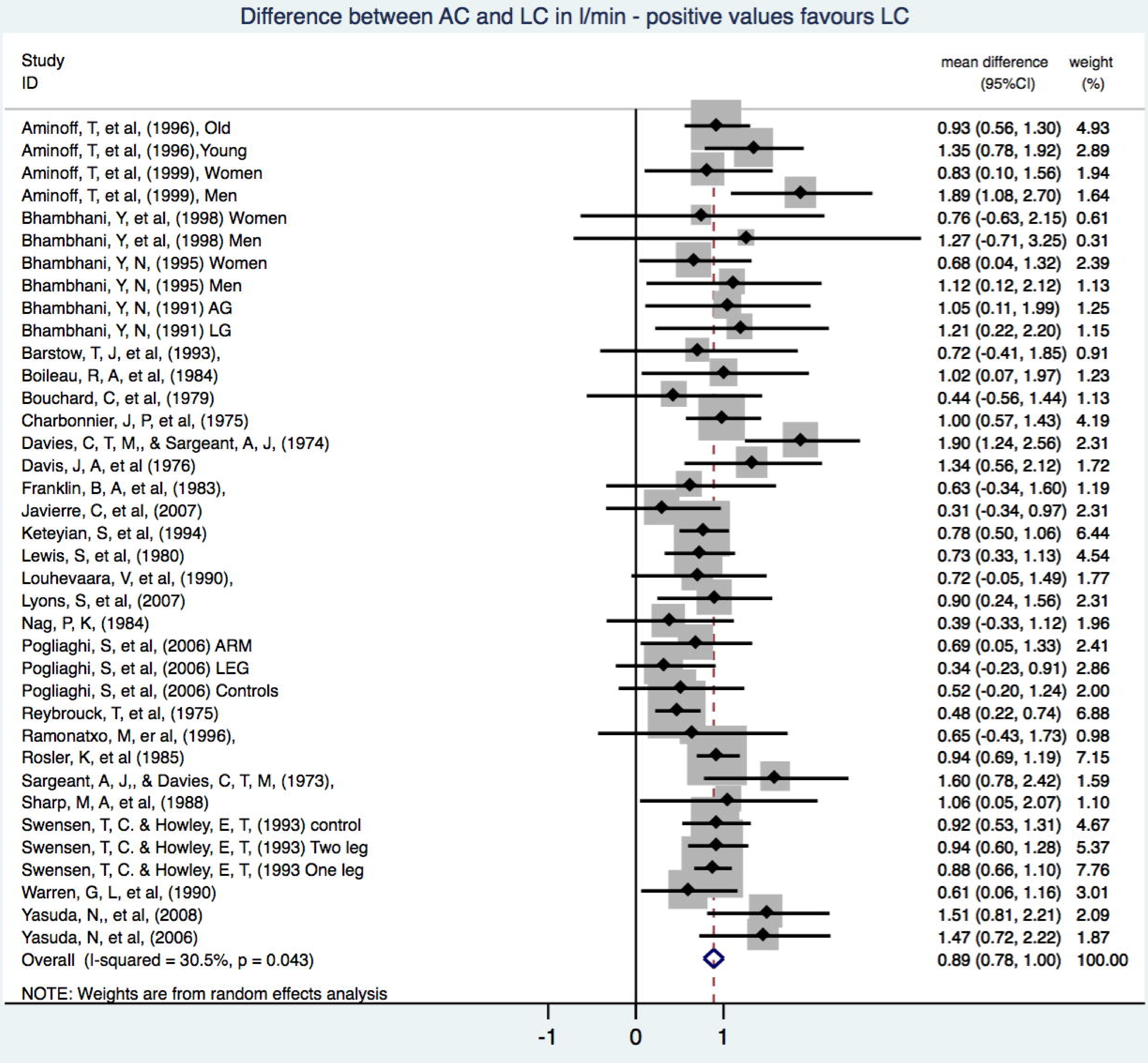
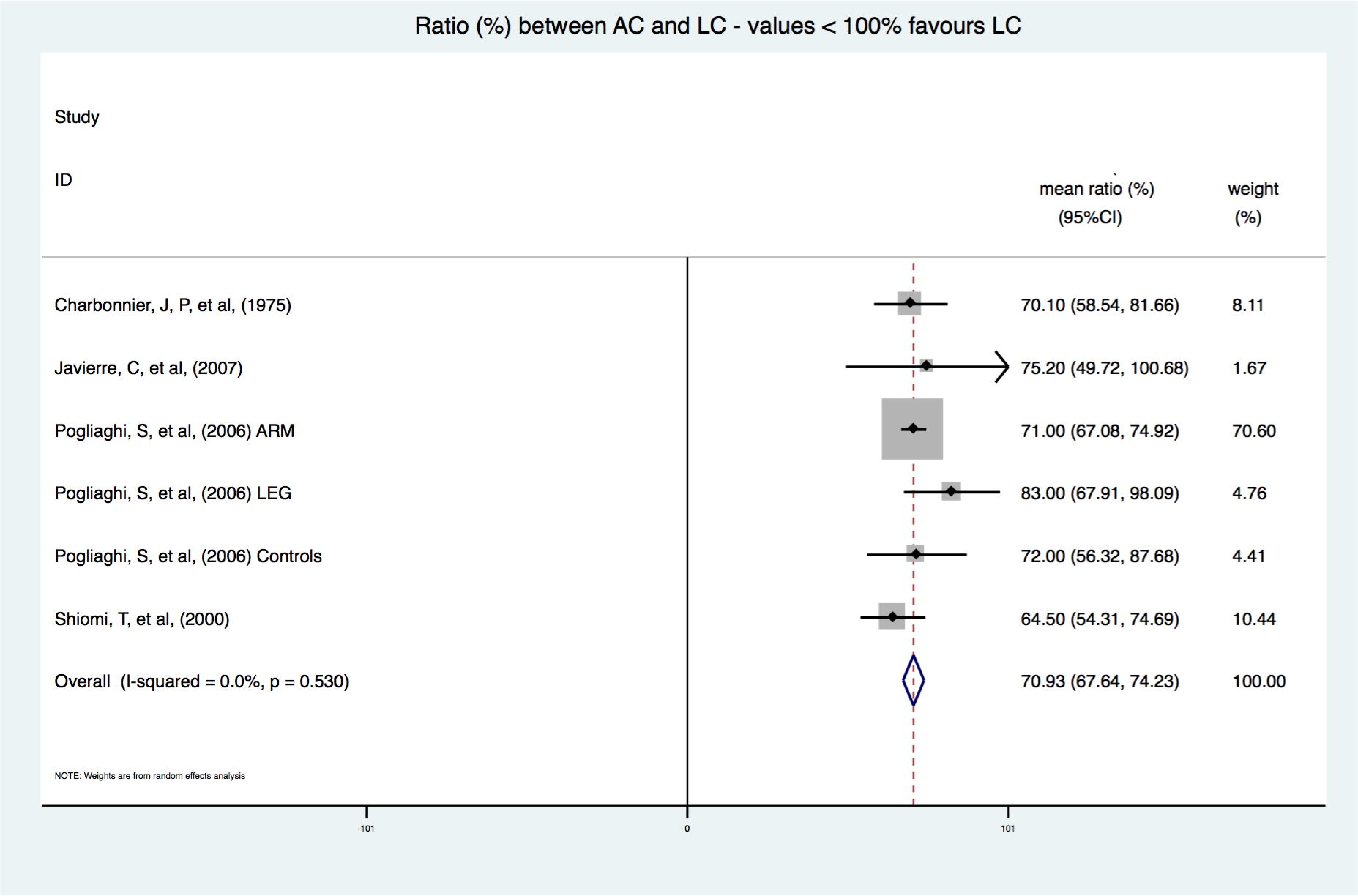

3,300 of records identified through database searching 10th of April 2015
Medline (n=1138)
Embase (n=1512)
CINAHL (n=354)
Pedro (n=296)
No additional records identified through other sources
2683 of records after duplicates removed
617 of duplicates removed
2510 of records excluded due to:
Lack of AC test (n=672)
Lack of LC test (n=476)
Lack of outcome (n=1362)
2683 of records screened
131 of full-text articles excluded due to:
Study design (n=9)
Age (n=18)
Lack of AC test (n=40)
Lack of LC test (n=6)
Lack of outcome (n=13)
No within comparison data (n=1)
Assisted testing (n=1)
Athlete population (n=18)
Patient population (n=14)
Unobtainable study (n=9)
Lack of data (n=1)
173 of full-text articles assessed for eligibility
41 of studies included in the systematic review and meta-analysis

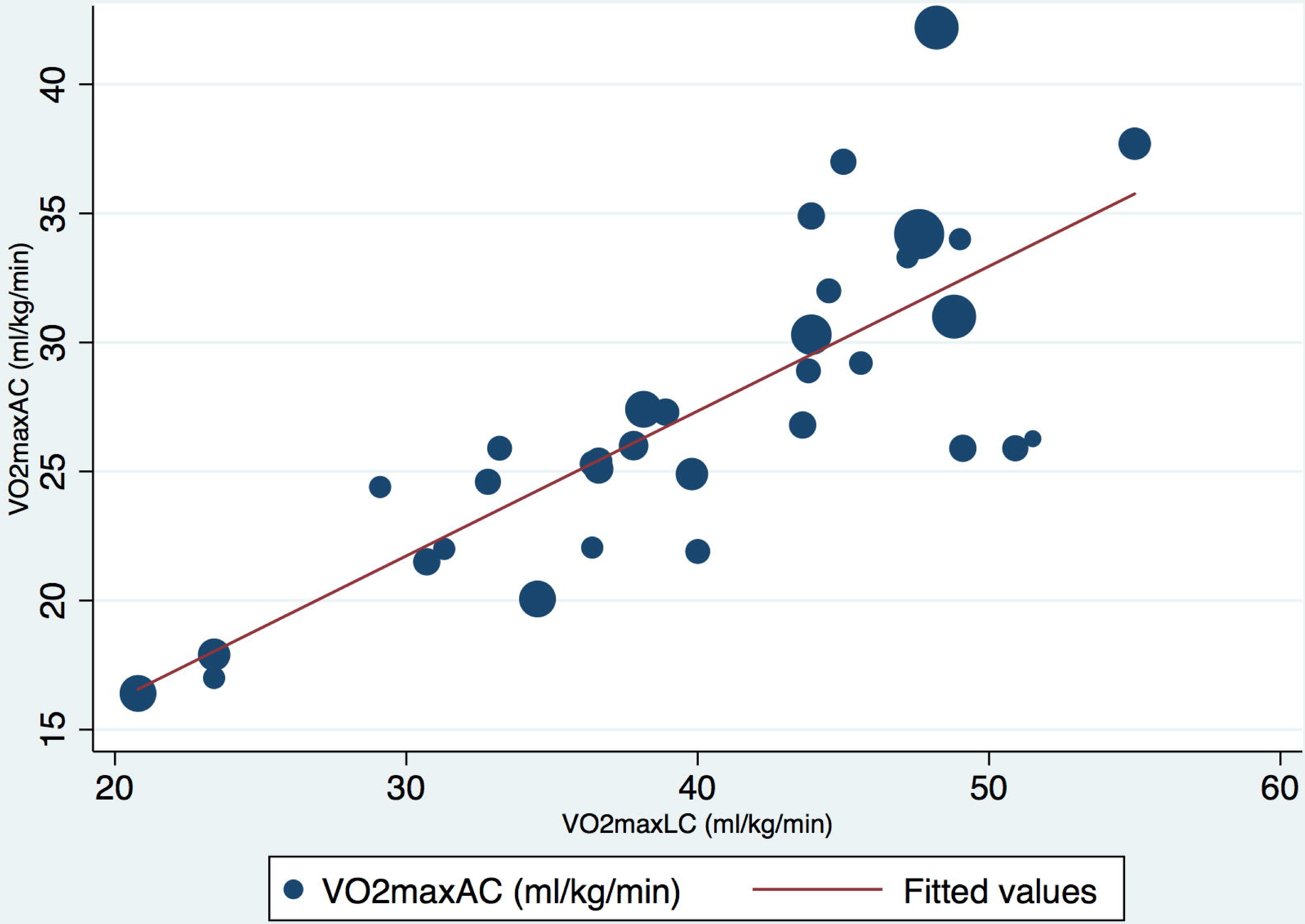

Research question
Study population
Participation rate
Inclusion and exclusion criteria
Sample size
Outcome measures
Blinding of outcome assessors
Confounding variables
0%
25%
50%
75%
100%
Low risk of bias
Unclear risk of bias
High risk of bias


Difference between AC and LC in ml/kg/min - positive values favours LC
Study
ID
mean difference
(95%CI)
weight
(%)
Aminoff, T, et al, (1996), Old 11.10 (7.05, 15.15) 5.37
Aminoff, T, et al, (1996),Young 16.80 (6.08, 27.52) 2.60
Aminoff, T, et al, (1999), Women 14.33 (1.09, 27.57) 1.97
Aminoff, T, et al, (1999), Men 25.23 (19.32, 31.14) 4.47
Bhambhani, Y, et al, (1998) Women 11.60 (-6.06, 29.26) 1.28
Bhambhani, Y, et al, (1998) Men 17.30 (-4.97, 39.57) 0.87
Bhambhani, Y, N, (1995) Women 11.50 (-0.84, 23.84) 2.17
Bhambhani, Y, N, (1995) Men 13.60 (0.95, 26.25) 2.10
Bhambhani, Y, N, (1991) AG 12.50 (1.83, 23.17) 2.61
Bhambhani, Y, N, (1991) LG 14.90 (4.05, 25.75) 2.56
Boileau, R, A, et al, (1984) 13.40 (1.59, 25.21) 2.30
Bond, V, et al, (1986), 18.10 (7.24, 28.96) 2.56
Bouchard, C, et al, (1979) 6.00 (-6.27, 18.27) 2.19
Castro, R, et al, (2011), 11.80 (8.27, 15.33) 5.61
Charbonnier, J, P, et al, (1975) 13.90 (8.99, 18.81) 4.95
Davis, J, A, et al (1976) 17.80 (8.17, 27.43) 2.94
Dekerle, J, et al, (2002) 10.73 (0.98, 20.48) 2.90
Franssen, F, M, et al, (2002) 4.39 (2.03, 6.75) 6.08
Javierre, C, et al, (2007) 5.50 (-5.41, 16.41) 2.54
Lyons, S, et al, (2007) 9.20 (-4.05, 22.45) 1.97
Orr, J, L, et al, (2013) 14.90 (2.65, 27.15) 2.20
Pogliaghi, S, et al, (2006) ARM 9.30 (1.63, 16.97) 3.68
Pogliaghi, S, et al, (2006) LEG 4.70 (-5.28, 14.68) 2.82
Pogliaghi, S, et al, (2006) Controls 6.40 (1.12, 11.68) 4.77
Rathnow, K, M,, & Mangum, M, (1990) Mixed mode group 7.30 (-6.37, 20.97) 1.89
Rathnow, K, M,, & Mangum, M, (1990) Single mode group 8.20 (-1.56, 17.96) 2.90
Rathnow, K, M,, & Mangum, M, (1990) Control group 13.20 (-0.62, 27.02) 1.86
Sawka, M, N, Et al, (1983) 8.00 (-4.85, 20.85) 2.06
Shiomi, T, et al, (2000) 16.40 (7.73, 25.07) 3.28
Sporer, B, C, et al, (2007) 13.70 (5.36, 22.04) 3.41
Turner, D, L, et al, (1997) 15.00 (11.61, 18.39) 5.67
Warren, G, L, et al, (1990) 11.20 (-4.61, 27.01) 1.52
Yasuda, N,, et al, (2008) 25.00 (11.62, 38.38) 1.94
Yasuda, N, et al, (2006) 23.20 (9.91, 36.49) 1.96
Overall (I-squared = 59.9%, p = 0.000) 12.52 (10.29, 14.75) 100.00
NOTE: Weights are from random effects analysis
-10
0
10


Difference between AC and LC in l/min - positive values favours LC
Study
ID
mean difference
(95%CI)
weight
(%)
Aminoff, T, et al, (1996), Old
0.93 (0.56, 1.30) 4.93
Aminoff, T, et al, (1996),Young
1.35 (0.78, 1.92) 2.89
Aminoff, T, et al, (1999), Women
0.83 (0.10, 1.56) 1.94
Aminoff, T, et al, (1999), Men
1.89 (1.08, 2.70) 1.64
Bhambhani, Y, et al, (1998) Women
0.76 (-0.63, 2.15) 0.61
Bhambhani, Y, et al, (1998) Men
1.27 (-0.71, 3.25) 0.31
Bhambhani, Y, N, (1995) Women
0.68 (0.04, 1.32) 2.39
Bhambhani, Y, N, (1995) Men
1.12 (0.12, 2.12) 1.13
Bhambhani, Y, N, (1991) AG
1.05 (0.11, 1.99) 1.25
Bhambhani, Y, N, (1991) LG
1.21 (0.22, 2.20) 1.15
Barstow, T, J, et al, (1993),
0.72 (-0.41, 1.85) 0.91
Boileau, R, A, et al, (1984)
1.02 (0.07, 1.97) 1.23
Bouchard, C, et al, (1979)
0.44 (-0.56, 1.44) 1.13
Charbonnier, J, P, et al, (1975)
1.00 (0.57, 1.43) 4.19
Davies, C, T, M,, & Sargeant, A, J, (1974)
1.90 (1.24, 2.56) 2.31
Davis, J, A, et al (1976)
1.34 (0.56, 2.12) 1.72
Franklin, B, A, et al, (1983),
0.63 (-0.34, 1.60) 1.19
Javierre, C, et al, (2007)
0.31 (-0.34, 0.97) 2.31
Keteyian, S, et al, (1994)
0.78 (0.50, 1.06) 6.44
Lewis, S, et al, (1980)
0.73 (0.33, 1.13) 4.54
Louhevaara, V, et al, (1990),
0.72 (-0.05, 1.49) 1.77
Lyons, S, et al, (2007)
0.90 (0.24, 1.56) 2.31
Nag, P, K, (1984)
0.39 (-0.33, 1.12) 1.96
Pogliaghi, S, et al, (2006) ARM
0.69 (0.05, 1.33) 2.41
Pogliaghi, S, et al, (2006) LEG
0.34 (-0.23, 0.91) 2.86
Pogliaghi, S, et al, (2006) Controls
0.52 (-0.20, 1.24) 2.00
Reybrouck, T, et al, (1975)
0.48 (0.22, 0.74) 6.88
Ramonatxo, M, er al, (1996),
0.65 (-0.43, 1.73) 0.98
Rosler, K, et al (1985)
0.94 (0.69, 1.19) 7.15
Sargeant, A, J,, & Davies, C, T, M, (1973),
1.60 (0.78, 2.42) 1.59
Sharp, M, A, et al, (1988)
1.06 (0.05, 2.07) 1.10
Swensen, T, C. & Howley, E, T, (1993) control
0.92 (0.53, 1.31) 4.67
Swensen, T, C. & Howley, E, T, (1993) Two leg
0.94 (0.60, 1.28) 5.37
Swensen, T, C. & Howley, E, T, (1993 One leg
0.88 (0.66, 1.10) 7.76
Warren, G, L, et al, (1990)
0.61 (0.06, 1.16) 3.01
Yasuda, N,, et al, (2008)
1.51 (0.81, 2.21) 2.09
Yasuda, N, et al, (2006)
1.47 (0.72, 2.22) 1.87
Overall (I-squared = 30.5%, p = 0.043)
0.89 (0.78, 1.00) 100.00
NOTE: Weights are from random effects analysis
-1
0
1



Ratio (%) between AC and LC - values < 100% favours LC
Study
ID
mean ratio (%)
(95%CI)
weight
(%)
Charbonnier, J, P, et al, (1975)
70.10 (58.54, 81.66)
8.11
Javierre, C, et al, (2007)
75.20 (49.72, 100.68)
1.67
Pogliaghi, S, et al, (2006) ARM
71.00 (67.08, 74.92)
70.60
Pogliaghi, S, et al, (2006) LEG
83.00 (67.91, 98.09)
4.76
Pogliaghi, S, et al, (2006) Controls
72.00 (56.32, 87.68)
4.41
Shiomi, T, et al, (2000)
64.50 (54.31, 74.69)
10.44
Overall (I-squared = 0.0%, p = 0.530)
70.93 (67.64, 74.23)
100.00
NOTE: Weights are from random effects analysis
-101
0
101



40
35
30
25
20
15
VO2maxAC (ml/kg/min)
20
30
40
50
60
VO2maxLC (ml/kg/min)
VO2maxAC (ml/kg/min)
Fitted values

Table 1 - Study Characteristics of the 53 groups from the 41 included studies

Continent of publication	**(%)**
North America	56.6 %
Europe	35.8 %
South America	3.8 %
Asia	3.8 %
Study Design	
RCT	17.0 %
Non-RCT	3.8 %
Cross-sectional	79.2 %
Study risk of bias	**Median (IQR)**
SumQAT	4 points (3 to 5)
Participant characteristics	
Gender	**(%)**
Male only	66 %
Female only	15.1 %
Mixed	15.1 %
Not reported	3.8 %
	Median (IQR)
Mean age years	28.4 years (25 to 32.3)
Mean BMI, kg/m^2	23.65 kg/m^2 (22.7 to 25)
Aerobic capacity	**(%)**
Low	3.8 %
Average	28.7 %
Good	5.6 %
High	3.8 %
Did not report	58.1 %
Test characteristics	
Order on AC/LC test	**(%)**
AC first	3.8 %
LC first	18.9 %
Random order	45.3 %
Not reported	32 %
	Median (IQR)
Time between tests (hours)	72 (24 to 168)
AC start level (watts)	25 (15 to 40)
LC start levels (watts)	50 (30 to 50)
AC increase/min (watt)	10.7 (5 to 17)
LC increase/min (watt)	30 (20.7 to 30)

IQR: Interquartile range, SumQAT: sum of quality assessment tool score, AC: Arm cycle, LC: Leg cycle

***Table 2* –** Meta-regression analyses performed on each variable (univariable) and adjusted for all variables (multivariable)

Univariable meta-regression on $ACLC_{diff}$	**Groups included in analysis**	**Mean coefficient (95% CI)**	**p-value**
Aerobic capacity	27	4.1 (95% CI: 1.5 to 6.6)	p=0.003
Gender distribution (% male)	33	-1.25 (95% CI: -7.4 to 4.9)	p=0.684
Mean age	29	-2.1 (95% CI: -0.3 to -0.1)	p<0.001
Mean difference in peak RER values	24	-12.1 (95% CI: -68.8 to 44.6)	p=0.663
Risk of bias (SumQAT score)	34	-0.19 (95% CI: -2.6 to 2.2)	p=0.875
Multivariable meta-regression on $ACLC_{diff}$			
Aerobic capacity	16	4.0 (95% CI: 0.81 to 7.2)	p=0.019
Gender distribution (% male)	16	4.5 (95% CI: -4.1 to 13.2)	p=0.268
Mean age (years)	16	-0.25 (95% CI: -0.4 to -0.06)	p=0.014
Mean difference in peak RER values	16	7.9 (95% CI: -59.0 to 74.8)	p=0.797
Risk of bias (SumQAT score)	16	0.9 (95% CI: -3.8 to 5.6)	p=0.682

$ACLC_{diff}$: difference between obtained AC VO_{2max} and obtained LC VO_{2max}, 95% CI: 95% confidence intervals, RER: respiratory exchange ratio, SumQAT: sum of quality assessment tool score