Neck circumference in Latin America and the Caribbean: A systematic review and meta-analysis [version 1; peer review: 2 approved]

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Abstract

Background: High neck circumference (NC) is associated with high burden diseases in Latin American and the Caribbean (LAC). NC complements established anthropometric measurements for early identification of cardio-metabolic and other illnesses. However, evidence about NC has not been systematically studied in LAC. We aimed to estimate the mean NC and the prevalence of high NC in LAC.

Methods: We conducted a systematic review in MEDLINE, Embase, Global Health and LILACS. Search results were screened and studied by two reviewers independently. To assess risk of bias of individual studies, we used the Hoy et al. scale and the Newcastle-Ottawa scale. We conducted a random-effects meta-analysis.

Results: In total, 182 abstracts were screened, 96 manuscripts were reviewed and 85 studies (n= 51,978) were summarized. From all the summarized studies, 14 were conducted in a sample of the general population, 23 were conducted with captive populations and 49 studies were conducted with patients. The pooled mean NC in the general population was 35.69 cm (95% IC: 34.85cm-36.53cm; I²: 99.6%). In our patient populations, the pooled mean NC in the obesity group was 42.56cm (95% CI 41.70cm-43.42cm; I²: 92.40%). Across all studied populations, there were several definitions of high NC; thus, prevalence estimates were not comparable. The prevalence of high NC ranged between 37.00% and 57.69% in the general population. The methodology to measure NC was not consistently reported.

Conclusions: Mean NC in LAC appears to be in the range of estimates from other world regions. Inconsistent methods and definitions hamper cross-country comparisons and time trend analyses. There is a need for consistent and comparable definitions of NC so that it can be incorporated as a standard anthropometric indicator in surveys.
and epidemiological studies.

**Keywords**
Anthropometrics, cardio-metabolic risk factor, obesity

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Abbreviations
Body Mass Index: BMI, Latin American and the Caribbean: LAC, Neck Circumference: NC, Obstructive Sleep Apnea - Hypopnea Syndrome: OSAHS, Waist Circumference: WC

Introduction
Anthropometric indicators have an important role in public health because they are risk factors or diagnostic criteria for some highly prevalent non-communicable diseases (e.g., cancers and cardio-metabolic diseases)\(^1\)-\(^4\). Weight, height, body mass index (BMI) and waist circumference (WC) have been broadly studied in terms of prevalence and time trends\(^5\)-\(^9\), and their long-term association with health outcomes has been studied by large cohorts in many world regions\(^1\)-\(^3\). This evidence for neck circumference (NC) lacks globally and in Latin American and the Caribbean (LAC), where novel and inexpensive anthropometric indicators could contribute to the prevention and early identification of non-communicable diseases\(^6\)-\(^8\).

Unlike BMI, there have been no efforts to summarize mean NC and prevalence estimates of high NC in LAC. This evidence could provide a baseline parameter of this anthropometric indictor to inform future research and surveillance plans, while also characterizing population groups in terms of their NC profile. In addition, a critical appraisal of the available evidence about NC in LAC lacks, thus research gaps, needs and methodological issues have not been identified to improve the formulation of future research. With evidence that NC appears to be a risk factor for many diseases (e.g. cardio-metabolic diseases and obstructive sleep apnea), in a similar magnitude as other anthropometric indicators\(^7\)-\(^10\), it becomes relevant to understand the current status of NC so that it could be incorporated in population-based surveys or epidemiological studies.

To summarize the evidence about NC in LAC, to provide pooled estimates of mean levels and prevalences, and to highlight research needs and methodological caveats, we conducted a systematic review and meta-analysis of the scientific evidence about NC in LAC populations.

Methods
Protocol and registration
This is a systematic review of the scientific literature with meta-analysis of summary data. The methodology and reporting followed the PRISMA guideline (see reporting guidelines)\(^1\). The protocol was prepared before conducting the review and is available online\(^3\).

Eligibility criteria
This review included original studies with the following populations: LAC adults either from the general population, captive/closed populations (e.g., workers) or patients from any healthcare facility. We excluded patients who had conditions that could have biased the NC measurement (e.g., cervical masses, thyroid diseases, cervical fractures or congenital anomalies). We excluded studies with LAC immigrants in countries outside the LAC region. Studies should have reported that NC was measured, regardless of the methodology; in other words, if NC was not directly measured (i.e., NC was self-reported), this study was excluded. We excluded case reports, case series, letters, editorials, narrative reviews, clinical trials and systematic reviews.

Information sources and search
We conducted the search in MEDLINE, Embase and Global Health, these three were searched through OVID; we also searched LILACS, a LAC specific search engine. The search was conducted on 27 September 2020. The complete search strategy is available as extended data\(^3\).

Study selection
First, two authors (KFL, RPSM / PEL, JQA) independently screened the titles and abstracts of the search results. Second, the same reviewers independently studied the full text of the selected articles. Likewise, the full text of the selected articles was analyzed to ensure that multiple publications of the same study were included once only (e.g., national survey with multiple publications). Discrepancies between reviewers were resolved by consensus between them or by discussions with a third reviewer (RMC-L). If the information reported in the original article was not enough to assess the eligibility criteria, we tried to contact the corresponding author of these studies. Those articles which corresponding authors did not answer to our communications after two weeks were excluded from this review.

Data collection process
Two authors (KFL, RPSM / PEL, JQA) independently extracted the information from the included articles using a standard form for each of the population groups herein studied (general population, captive population and patients). Any differences between the two reviewers were resolved by consensus between them or by discussions with a third reviewer (RMC-L). The extraction form we used was developed before data collection and was not modified during the extraction process.

Data items
The following information was extracted from all articles: title, first author, country, publication year, year of data collection, study design, sample size, mean age and age range of the study population, men proportion, instrument and method to measure NC, cut-off point of high NC overall and by gender, prevalence of high NC overall and by gender, and mean NC overall and by gender. From articles with a sample of the general population, we also extracted information on whether it was a national sample. From articles with a captive population, we also extracted the origin of the population (e.g., students or elderly in nursing homes). From articles with patients we recorded the underlying disease. Additionally, the following information was extracted from the case-control studies: proportion of cases and controls, mean NC for cases and controls, and prevalence of high NC for cases and controls.

Risk of bias of individual studies
Two authors (KFL, RPSM / PEL, JQA) independently assessed the risk of bias of the articles using the risk of bias tool for prevalence studies by Hoy et al.\(^1\); we used the Newcastle-Ottawa scale for the case-control and cohort studies\(^6\). Discrepancies between the two reviewers were solved by discussion with a third reviewer (RMC-L). Items that did not apply
(e.g., acceptable case definition for prevalence studies) to our selected reports were not assessed.

Synthesis of results
We conducted a quantitative synthesis (meta-analysis) of mean NC only, because evidence from prevalence estimates was largely heterogeneous (e.g., different definitions) and scarcer than for mean estimates. We decided to conduct the meta-analysis when there were at least three individual estimates. We only conducted the meta-analysis for overall mean estimates (i.e., not sex-stratified). Using the mean estimates along with the corresponding standard errors computed from the confident intervals [standard error = (upper limit - lower limit)/3.92], we conducted a random-effects meta-analysis in STATA v16.1 (College Station, Texas 77845 USA); we used the metan function with the randomi option for a random-effects model following the DerSimonian & Laird method.

Ethics
This is a systematic review of the scientific literature in which human subjects were not directly studied. We did not request approval by an Ethics Committee. All authors had access to the collated data and are collectively responsible for the accuracy of results and conclusions. All authors approved the submitted version. The funder had no role in the study design, analyses, interpretation or conclusions.

Results
Study selection
The article search yielded 323 results; of these, 182 titles and abstracts were screened and then, 96 manuscripts were studied. We finally included 85 (n=51,978) studies (Figure 1) 16-100.

Neck circumference in the general population
Of the total selected articles, 14 studies 16-25 were conducted in a sample of the general population (one study also contributed to the captive population group13). The 14 studies followed a cross-sectional design. Most of them were from Brazil (10) 16-18,20-24,26,28 while the rest were from Argentina12, Chile29, Colombia32 and Venezuela33. The age of the study population was ≥18 years old, except in one study which was ≥15 years35. The total sample was 24,401, with a mean age of 39.73 years. The instrument or methodology to measure NC was detailed in 11 studies (Table 1) 15-19,21-27,29.

Mean NC was available from 12 articles (n=20,284) 16,17,19-24,26-28, though the pooled mean NC was based on 11 estimates 16,19-24,26-29; the overall pooled mean NC was 35.69cm (95% IC: 34.85cm-36.53cm; P: 99.6%) (Table 1). The minimum and maximum mean NC in men were 38.17cm and 39.70cm, respectively; while these numbers in women were 33.11cm and 35.90cm, respectively (Table 1). The prevalence of high NC was available from 3 studies 11,12,15, all of which used different thresholds for men and women; for men, the cut-off points ranged between 37cm and 41cm, while for women the range was between 34cm and 35cm. Based on these definitions, the prevalence of high NC in the general population went from 37.00% to 57.69% (Table 1). One study19 reported the prevalence of high NC stratified by sex; for men, high NC was defined at >39cm while for women this cut-off point was >35cm, yielding a prevalence of 48.70% in men and 44.80% in women (Table 1).

Neck circumference in captive populations
Of the total selected articles, 23 reports30-51 included captive populations and 138 of these reports provided 2 estimates (i.e., two different populations). Studies followed a cross-sectional, case-control and cohort design. Most of the articles were from Brazil (19)30-33,37-45,48-51 while the others were from Chile (3)30,36,46 and Peru (1)37. The instrument and methodology to measure NC was reported in 19 studies (Table 2) 39,31-34,36,37,39-46,48,49,51.

Of the 23 articles in this group, 22 articles (n=18,173) reported the mean NC. Additionally, 14 studies 29,31-36,41-45,48-51 established different cut-off points for high NC for men and women, with a minimum and maximum value for men of 37cm and 42cm, respectively; while the values for women were 34 cm and 36.10 cm, respectively (Table 2). From all the captive population articles, 4 of these included university students31,32,34,47 and also reported the mean NC (Table 2). The minimum and maximum mean NC in this captive population were 33.66cm and 37.10cm, respectively; in men were 39.19cm and 40.20cm, respectively; and in women the minimum and maximum values were 32.02cm and 33.50cm, respectively (Table 2).

Of all the articles with captive populations, 4 of these included elderly people9,42,44,45 and also reported the mean NC. The minimum and maximum mean NC in this captive population were 34.60cm and 36.94cm, respectively; in men were 39.19cm and 40.20cm, respectively; and in women the minimum and maximum values were 33.50cm and 36.38cm, respectively (Table 2).

The prevalence of high NC was available from 3 studies11,42,50 of all which used different thresholds for men and women; for men, the cut-off points ranged between 34cm and 40.5cm, while for women the range was between 34cm and 35cm (Table 2). Based on these definitions, the prevalence of high NC in the overall sample of captive populations went from 54.25% to 62%; while for men and women it went from 50.79% to 56.66%, from 50.22% to 62.10% and from 50.22% to 62.10% respectively (Table 2).

Neck circumference in patients
Of the total selected studies, 49 reports32-100 were conducted with patients. Studies followed a cross-sectional, case-control and cohort design. Most of the articles were from Brazil (35)32-35,37,39,41,42,45,76,78,79,80,81,91,93,95-97,99 while the others were from Chile (5)34,68,73,90,94, Mexico (4)64,67,81,100, Peru (3)35,97,99 and Argentina (2)58,98. The most frequently studied patients were those with Obstructive Sleep Apnea - Hypopnea Syndrome (OSAHS) (22)35,37,38,42,44,45,49,50,78,89,91,93,95,97,99 and obesity (13)52,71,73,80,82,85,91,92,95,99,100; other diseases included HIV/AIDS,
sleep disorders, bronchiectasis, depression, stroke, epilepsy, hepatic and cardiovascular pathologies. The instrument or methodology to measure NC was reported in 29 studies. We found 1 report, which contributed with 2 estimates (e.g., one report provided more than one set of estimates).

Of the 49 studies in this group, 44 studies reported the mean NC. The overall pooled mean NC in patients with OSAHS (19 estimates; n=4,141) was 41.09 cm (95% CI 40.42 cm-41.77 cm; I²: 94.80%), and for those with obesity (13 estimates; n=1,952) was 41.09 cm (95% CI 40.42 cm-41.77 cm; P: 94.80%), and for those with obesity (13 estimates; n=1,952) was 41.09 cm (95% CI 40.42 cm-41.77 cm; P: 94.80%).
Table 1. Synthesis of population-based studies.

| First Author | Country | Data Year | Study Design | Sample | Mean Age | Age Range | Men Proportion | Instrument | Measured How | Cut Point for Men (cm) | Cut Point for Women (cm) | Mean Overall | Mean Men | Mean Women | Prevalence Elevated Overall | Prevalence Elevated Men | Prevalence Elevated Women | Contribution to Meta-analysis |
|--------------|---------|-----------|--------------|--------|----------|-----------|----------------|------------|--------------|------------------------|--------------------------|---------------|---------|-----------|-----------------------------|-------------------------|--------------------------|--------------------------|
| Moraes, W., et al. | Brazil | 2018 | Cross-sectional | 130 | ≥18 | 32.31 | Measuring tape | The cricothyroid cartilage height level was used as a reference for the measurement. For men, the NC was measured just below the cartilage because of the greater prominence of this region. | 37.00 | 34.00 | 57.69 | No |
| Neves, T., et al. | Brazil | 2015 | Cross-sectional | 1132 | 15–65 | 48.76 | Measuring tape | | 39.00 | 35.00 | 36.17 | Yes |
| Ribeiro, L., et al. | Brazil | 2014 | Cross-sectional | 950 | 47.40 | ≥18 | 34.64 | Measuring tape | At the middle high of the neck, below the laryngeal prominence (Adam’s apple), around the neck, parallel to the floor. | 39.50 | 34.50 | 35.50 | Yes |
| Méndez-Pérez, B., et al. | Venezuela | 2016 | Cross-sectional | 365 | 43.90 | ≥18 | 48.40 | Measuring tape | | 41.00 | 35.00 | 0.37 | No |
| Leite, J., et al. | Brazil | 2013 | Cross-sectional | 993 | 41.80 | 20–80 | 46.12 | At the level of the cricothyroid membrane. | 4.00 | 38.00 | 36.33 | Yes |
| Volaco, A., et al. | Brazil | 2010 | Cross-sectional | 1042 | 20.20 | 20–80 | 44.91 | Measuring tape | | 36.20 | 39.40 | 33.60 | Yes |
| Mora, R., et al. | Chile | 2015 | Cross-sectional | 4906 | 31.50 | ≥15 | 40.00 | Measuring tape | At the level of most prominence of the cricoid cartilage (Adam’s apple). | 4.00 | 35.00 | 36.90 | Yes |
| First Author | Country | Data Year | Study Design | Population Type                          | Sample | Mean Age | Age Range | Men Proportion | Instrument                     | Measured How                                                                                     | Cut Point Mean | Cut Point Women | Mean Overall | Mean Men | Mean Women | Prevalence Elevated Overall | Prevalence Elevated Men | Prevalence Elevated Women |
|-------------|--------|-----------|--------------|------------------------------------------|--------|----------|-----------|----------------|-------------------------------|----------------------------------------------------------------------------------|----------------|----------------|-------------|----------|------------|-----------------------------|------------------------|--------------------------|
| Tavares, C. et al. | Brazil | 2011 | Cross-sectional | Healthcare professionals | 159 | 43.20 | 21.38 | 21.38 | Measuring tape | Above the thyroid cartilage prominence. | 39.60 | 36.10 | 33.66 | 36.95 | 32.02 |
| Dantas, E. et al. | Brazil | 2010 | Cross-sectional | University students | 406 | 20.95 | 18 - 58 | 37.80 | Measuring tape | Below the superior border of the prominence of the larynx. | 39.00 | 35.00 | 37.10 |
| De Siquiera, K. et al. | Brazil | 2011 | Cross-sectional | University students | 159 | 43.20 | 21.38 | 39.30 | Measuring tape | Midpoint of the neck height | 34.00 | 33.00 | 33.00 |
| Alves, H. et al. | Brazil | 2010 | Cross-sectional | Female nurse | 71.0 | 42.00 | 18 - 59 | 0.00 | Measuring tape | The measuring tape was positioned just below the top edge of the laryngeal prominence. | 39.00 | 35.00 | 33.70 |
| Santosa, D. et al. | Brazil | 2008 | Cross-sectional | Professional urban bus drivers | 404 | 38.20 | ≥18 | 100.00 | Measuring tape | Right above the cricoid cartilage and perpendicular to the long axis of the neck, with the participant in a sitting position. | 36.62 | 39.50 | 33.90 |
| Pacheco, A. et al. | Chile | 2004 | Case-Control | Japanese descendants in São Paulo, Brazil | 1221 | 51.50 | 35 - 74 | 48.50 | Measuring tape | The base of the neck, below the laryngeal prominence. | 35.11 | 39.70 | 33.50 |
| Hausherr, M. et al. | Brazil | 2004 | Cross-sectional | Active or retired civil servants of universities or research institutions | 152 | 53.30 | ≥18 | 100.00 | Measuring tape | Just above the cricoid cartilage and perpendicular to the long axis of the neck. | 40.00 | 42.00 |
| Genta, P. et al. | Brazil | 2012 | Cross-sectional | Elderly at a health center | 411 | 70.00 | ≥18 | 26.00 | Measuring tape | The base of the neck, below the laryngeal prominence. | 35.11 | 39.70 | 33.50 |
| Nogueira, M. et al. | Brazil | 2015 | Cross-sectional | Adults attending at a health center | 126 | 36.30 | 18 - 59 | 19.00 | Measuring tape | At the base of the neck, at the height of the cricoid cartilage. In men with prominence, NC was measured below prominence. | 37.00 | 34.00 | 36.10 | 40.10 | 34.50 | 54.80 | 86.70 | 41.80 |
| Carvalho, P. et al. | Brazil | 2015 | Cross-sectional | Elderly at a health center | 405 | 65.28 | ≥18 | 14.80 | Measuring tape | Just above the cricoid cartilage and perpendicular to the long axis of the neck. | 40.50 | 35.70 | 36.94 | 40.10 | 36.38 | 54.25 | 50.79 | 54.99 |
| First Author       | Country | Data Year | Study Design | Population Type                                           | Sample | Mean Age | Age Range | Men Proportion | Instrument               | Measured How                                                                 | Cut Point Men   | Cut Point Women | Mean Overall | Mean Men | Mean Women | Prevalence Elevated Overall | Prevalence Elevated Men | Prevalence Elevated Women |
|--------------------|---------|-----------|--------------|-----------------------------------------------------------|--------|----------|-----------|----------------|--------------------------|------------------------------------------------------------------------------|----------------|----------------|-------------|----------|-------------|-----------------------------|-------------------------|--------------------------|
| Da Silva, A. et al | Brazil  | 2011      | Cross-Sectional | General outpatient nutrition clinic of a public university hospital specialized in cardiology | 129    | 55.60    | ≥35       | 36.40          | Measuring tape          | Long the axis of the neck at the midpoint of the cervical spine to the midanterior of the neck | 37.00          | 34.00         | 36.60       | 40.30    | 35.70       |                                             |                         |                          |
| Closs, V. et al   | Brazil  | 2012      | Cross-Sectional | Elderly at a health center                                 | 513    | 68.50    | 60–103    | 36.37          | Over laryngeal prominence. |                                                                            | 36.86          | 39.19         | 35.53       |          |             |                                            |                         |                          |
| Petriça, G. et al | Brazil  | 2016      | Cross-Sectional | Elderly at a health center                                 | 170    | 66.50    | ≥60       | 0.00           | Measuring tape          | Above thyroid cartilage   | 34.60          | 34.60         |              |          |             |                                            |                         |                          |
| Pizarro-Montaner, C et al | Chile | 2011 | Cross-Sectional | Cohort Miners                                               | 111    | 34.70    | 25–44     | 100.00         | Measuring tape          | Below laryngeal prominence.       | 37.00          | 39.95         | 39.95       |          |             |                                            |                         |                          |
| Perrià, L. et al  | Peru    | 2011      | Cross-Sectional | Medical students                                            | 46     | 19.60    | 18–23     | 50.00          | Measuring tape          |                                                                            | 35.40          | 37.30         | 33.50       |          |             |                                            |                         |                          |
| Dias de Jesus, E et al | Brazil | 2011 | Cross-Sectional | Elderly caregivers                                          | 34     | 43.68    | ≥18       | 100.00         | Measuring tape          | Horizontal plane of Frankfort.     | 34.00          | 35.87         | 35.87       | 62.00    | 62.00       |                                            |                         |                          |
| Ferreira, A. et al | Brazil  | 2016      | Cross-Sectional | Mura abiria                                                | 495    | 42.10    | 18–81     | 42.20          | Measuring tape          |                                                                            | 37.00          | 34.00         | 36.68       |          |             |                                            |                         |                          |
| Ramires, AR et al  | Brazil  | 2011      | Cross-Sectional | Sedentary woman                                            | 60     | 33.90    | ≥18       | 0.00           | Measuring tape          | Below laryngeal prominence.       | 35.00          | 33.78         | 55.00       |          |             |                                            |                         |                          |
| Mora, R. et al    | Chile   | 2016      | Cross-Sectional | Outdoor Gym Users                                           | 1023   | 31.50    | ≥15       | 70.97          | Measuring tape          | Cricoid cartilage prominence.     | 41.00          | 35.00         | 38.22       | 39.30    | 35.60       |                                            |                         |                          |
| Spuríboldi, D. et al | Brazil | 2016 | Cross-Sectional | Sedentary women                                            | 100    | 44.59    | 25–75     | 0.00           | Measuring tape          | Cricoid cartilage level.        | 35.84          | 35.84         |             |          |             |                                            |                         |                          |
mean NC was 42.56 cm (95% CI 41.70 cm - 43.42 cm; P: 92.40%) (Table 3). In studies that included patients with OSAHS, the minimum and maximum mean NC were 37.40 cm and 44.50 cm, respectively (Table 3). Studies with obese patients, the minimum and maximum mean NC were 37.01 cm and 44.41 cm, respectively (Table 3).

Additionally, 12 studies established different cut-off points for elevated NC for men and women, with a minimum and maximum value for men of 37 cm and 43 cm, respectively; while the values for women were 34 cm and 41 cm, respectively. The prevalence of high NC was available from 7 studies, all of which used different thresholds for all, men and women. Overall, the cut-off points for high NC ranged between 40 cm and 42 cm; for men, the cut-off points ranged between 37 cm and 43 cm, while for women the range was between 34 cm and 41 cm (Table 3). Based on these definitions, the prevalence of high NC in the general sample of patient population went from 30.4% to 86.6%; while for men and women it went from 34.2% to 95%, and from 26.6% to 65.8%, respectively (Table 3).

Risk of bias of individual studies
From all the cross-sectional studies, only 4 studies are considered as a close representation of the general population. Finally, analyzing the risk of bias of the prevalence studies included, the majority represent a moderate risk (7,17,24,25,31,33-35,45,57,58,59,65,69,70,73,78,87,91,96,97); some are low risk (16,18,23,25,26,32,34,44,49) (16); no study represents a high risk (Table 4 – Table 6).

Regarding the risk of bias of the case-control studies, in all the studies (7) the sample selection adequately represented the corresponding cases. In addition, concerning the risk of bias of the cohort studies (7,8,10,12,14,90,91), all the studies had an adequate follow-up of the cohorts (Table 4 – Table 6).

Discussion
Summary of evidence
This is a systematic review and meta-analysis to estimate the mean NC and the prevalence of high NC in adults from LAC. We summarized evidence from 14 studies in the general population; 23 from captive populations (e.g., students); and 49 studies with patients (mostly OSAHS and obesity). The mean NC in the general population ranged between 33.60 cm and 36.98 cm, whilst the minimum was 34.2% and the prevalence of high NC in the general population ranged between 34 cm and 41 cm (Table 3). From all the cross-sectional studies, only 4 studies (7,19,22,25,29) were conducted with a nationally representative sample. Therefore, information on mean NC and prevalence of high NC at the national level is missing in most countries of LAC. NC is an inexpensive and non-invasive anthropometric indicator, as it is the case with BMI or WC. Once standard procedures to measure NC and standard thresholds to define high NC are defined, NC could be implemented in large national surveys (e.g., DHS or WHO STEPS) to expand the arsenal of anthropometric indicators strongly associated with morbidity and mortality of cardio-metabolic diseases.

Limitations of the reviewed reports
The main limitation we found in the original reports was the lack of details on how NC was measured; that is, they did not consistently report the instruments (e.g., inelastic tape) and how NC was assessed. The same problem was observed regarding the cut-off points to define high NC; that is, there were not consistent and comparable thresholds. These limitations have overall implications and for our review as well. First, the high heterogeneity in methods and definitions hampers comparisons across studies/countries; also, the heterogeneity makes it difficult to study time trends. Regarding our review, the inconsistent methods and lack of standard definitions could explain the large heterogeneity reported in the meta-analyses, and also prevented us from conducting more meta-analyses, for example of prevalence estimates. We argue that the dearth of homogenous reporting and methodology is due to the lack of international standardization in the measurement of NC, which could be explained by how novel this anthropometric indicator is. There is a need for an international standardized measurement of NC which would allow cross-country and time trends analyses.

Another limitation of the reviewed studies was that only 4 (19,22,25,29) were conducted with a nationally representative sample. Therefore, information on mean NC and prevalence of high NC at the national level is missing in most countries of LAC. NC is an inexpensive and non-invasive anthropometric indicator, as it is the case with BMI or WC. Once standard procedures to measure NC and standard thresholds to define high NC are defined, NC could be implemented in large national surveys (e.g., DHS or WHO STEPS) to expand the arsenal of anthropometric indicators strongly associated with morbidity and mortality of cardio-metabolic diseases.

Limitations of the review
Our review has some limitations. First, although we used major global search engines (MEDLINE, EMBASE and Global Health), and one specific for LAC (LILACS), we did not search grey literature sources. These sources could have contributed few more results to our review; however, we doubt they would have substantially changed the conclusions. Most likely, they would have exhibited the same -or more severe- limitations as those herein pinpointed. Second, some studies did not report all the information. Even though we tried to contact the authors of the reports with missing information, 6/16 answered to our requests. As NC becomes a more popular anthropometric indicator, and standard methods and definitions are established by international or regional organizations, we believe that studies including NC information would provide more comprehensive methods and results. Hopefully, our work would spark interest in NC and about the relevance to have standard procedures, as there are with BMI and other anthropometric indicators. Third, our review could not find estimates for all countries in LAC, and neither did other multi-country endeavors (e.g., ELANS). Therefore, we cannot conclusively state that our estimates represent the scenario across the region. Nonetheless, our work adds to the
Table 3. Synthesis of hospital-based studies.

| First Author | Country | Study Design | Disease | Sample | Mean Age | Men Proportion | Case Proportion | Instrument | Measure of Neck | Cut Point for Men (cm) | Cut Point for Women (cm) | Mean Overall | Mean Men | Mean Women | Mean Cases | Mean Controls | Prevalence Elevated Over all | Prevalence Elevated Men | Prevalence Elevated Women | Prevalence Elevated Cases | Prevalence Elevated Controls |
|--------------|---------|--------------|---------|--------|----------|----------------|----------------|-------------|---------------|----------------------|-------------------------|----------------|----------|------------|-------------|----------------|-----------------------------|------------------------|--------------------------|--------------------------|----------------------------|
| de Paiva, R, et al. | Brazil | Case-Control | Obesity | 45 | 46.50 | 31.10 | 68.90 | 43.40 | 44.60 | 39.50 | 47.20 |
| Zonato, A, et al. | Brazil | Cross-sectional | OSAHS/Public Clinic | 307 | 50.00 | 67.00 | 33.00 | 41.00 | 41.00 | 65.00 | 75.00 |
| Zonato, A, et al. | Brazil | Cross-sectional | OSAHS/Private Clinic | 317 | 48.00 | 87.00 | 13.00 | 43.00 | 43.00 | 43.00 | 43.00 |
| Sutherland, K, et al. | Brazil | Cross-sectional | OSAHS | 137 | 48.10 | 69.50 | 30.50 | 41.80 | 41.80 | 41.80 | 41.80 |
| Pinto, J, et al. | Brazil | Cross-sectional | Sleep disorders | 82 | 43.76 | 80.50 | 19.50 | 39.87 | 39.87 | 39.87 | 39.87 |
| Oliveira, N, et al. | Brazil | Cross-sectional | HIV/AIDS | 35 | 43.90 | 51.40 | 48.60 | 37.00 | 34.00 | 35.20 | 35.20 |
| Musman, S, et al. | Brazil | Cross-sectional | Sleep disorders | 323 | 44.80 | 59.13 | 40.87 | 40.00 | 42.00 | 37.00 | 42.00 |
| Salas, C, et al. | Chile | Cross-sectional | OSAHS | 1044 | 53.20 | 76.00 | 24.00 | 42.10 | 38.30 | 38.30 | 38.30 |
| Saban, M, et al. | Argentina | Cross-sectional | OSAHS | 302 | 56.00 | 55.96 | 44.04 | 40.00 | 42.00 | 37.00 | 42.00 |
| Moura, P, et al. | Brazil | Cohort | OSAHS | 102 | 46.70 | 55.90 | 44.10 | 38.47 | 40.86 | 35.44 | 38.47 |
| Straz, P, et al. | Brazil | Cross-sectional | OSAHS | 10 | 48.00 | 40.00 | 60.00 | 40.25 | 40.25 | 40.25 | 40.25 |
| De Castro, J, et al. | Brazil | Case-Control | OSAHS | 95 | 49.00 | 49.00 | 51.00 | 40.00 | 43.20 | 43.20 | 43.20 |
| Boemke, L, et al. | Brazil | Cross-sectional | Non-alcoholic fatty liver disease | 82 | 41.70 | 33.00 | 67.00 | 41.70 | 41.70 | 41.70 | 41.70 |
| Hiraj, M, et al. | Brazil | Cross-sectional | OSAHS | 48 | 34.00 | 79.20 | 20.80 | 40.00 | 40.00 | 38.00 | 100.00 |
| Borges, R, et al. | Brazil | Cross-sectional | OSAHS | 93 | 46.00 | 58.10 | 41.90 | 38.56 | 40.31 | 35.31 | 38.56 |
| Saldaña, R, et al. | Mexico | Cross-sectional | OSAHS | 10 | 44.00 | 60.00 | 40.00 | 41.80 | 41.80 | 41.80 | 41.80 |
| First Author          | Country | Study Design | Disease | Sample | Mean Age | Men Proportion | Case Proportion | Instrument Measured How | Neck Circumference (cm) | Cut Point (cm) for Men | Cut Point (cm) for Women | Men Mean | Men Overall | Men Mean | Women Mean | Men Mean | Cases | Mean Controls | Prevalence Elevated Overall | Prevalence Elevated Men | Prevalence Elevated Women | Prevalence Elevated Cases | Prevalence Elevated Controls |
|-----------------------|---------|--------------|---------|--------|----------|---------------|------------------|------------------------|-------------------------|------------------------|------------------------|----------|-------------|----------|-------------|----------|-------|------------|--------------------------|--------------------------|----------------------------|----------------------------|----------------------------|
| Castorena-Maldonado, A, et al. | Mexico | Case-Control | OSAHS   | 61     | 35.50    | 62.30         | 37.70            | Measuring tape       | At the level of the cricothyroid membrane. | 39.80      | 34.50      | 39.20    | 39.20      | 30.40   | 30.40 |
| Jorguera, A, et al.    | Chile   | Cross-Sectional | OSAHS   | 40     | 52.27    | 80.00         | 20.00            | Measuring tape       | 41.55      | 41.55      | 41.55    | 41.55      |         |       |
| De Castro, J, et al.   | Peru    | Cohort       | OSAHS   | 40     | 46.40    | 91.00         | 9.00             | Tape                | 37.00      | 34.00      | 34.00    | 34.00      | 30.40   | 30.40 |
| Rodriguez, A, et al.   | Brazil  | Cross-Sectional | Depression | 79     | XXX      | 24.10         | 75.90            | Measuring tape       | The participant standing upright and the measurement was taken at mid-neck height. | 39.80      | 34.50      | 34.50    | 34.50      |         |       |
| Aguirre, L, et al.     | Brazil  | Cross-Sectional | Obesity  | 38     | 42.00    | 13.16         | 86.84            | Measuring tape       | Horizontally at the level of the cricoid cartilage. | 45.00      | 41.00      | 42.00    | 42.00      | 40.60   | 40.60 |
| Chavarría-González, C, et al. | Peru | Cross-Sectional | Obesity  | 230    | 49.76    | 56.50         | 43.50            | Measuring tape       | Midpoint of the neck. | 37.66      | 37.66      | 37.66    | 37.66      |         |       |
| De Menezes, R, et al.  | Brazil  | Cross-Sectional | Obesity  | 1089   | 38.10    | 28.30         | 71.70            | Measuring tape       | At the level of the cricoid cartilage. | 42.00      | 42.00      | 42.00    | 42.00      | 42.00   | 42.00 |
| Corrêa, F, et al.      | Brazil  | Case-Control  | OSAHS   | 37     | 33.94    | 33.94         | 33.94            | Measuring tape       | 41.55      | 35.50      | 35.50    | 35.50      |         |       |
| Pires Jr., R, et al.   | Brazil  | Cohort       | OSAHS   | 28     | 40.80    | 52.10         | 47.90            | Measuring tape       | 38.30      | 38.30      | 38.30    | 38.30      |         |       |
| Farias, J, et al.      | Brazil  | Cross-Sectional | Bronchiectasis | 21     | 51.60    | 42.90         | 57.10            | Measuring tape       | 38.81      | 38.81      | 38.81    | 38.81      |         |       |
| Schmidek, V, et al.    | Brazil  | Cross-Sectional | Obstructive Sleep Apnea | 123     | 61.90    | 60.20         | 39.80            | Measuring tape       | Midpoint of the neck. | 37.66      | 37.66      | 37.66    | 37.66      |         |       |
| Amorim, T, et al.      | Brazil  | Cross-Sectional | Acute myocardial infarction | 34     | 68       | 58.8          | 41.2             | Measuring tape       | 37.30      | 34.70      | 34.70    | 34.70      | 36.10   | 36.10 |
| Neto, F., et al.       | Brazil  | Cross-Sectional | OSAHS   | 90     | 46       | 51            | 49               | Measuring tape       | 41.30      | 41.30      | 41.30    | 41.30      | 36.40   | 36.40 |
| Lopes, E, et al.       | Brazil  | Cross-Sectional | Obesity  | 147    | 40.71    | 34.69         | 65.31            | Measuring tape       | 42.30      | 45.40      | 45.40    | 45.40      | 39.14   | 39.14 |
| Freire, L, et al.      | Brazil  | Cross-Sectional | OSAHS   | 50     | 57.52    | 42            | 58               | Measuring tape       | Portal points stood up straight, with their heads positioned in the horizontal plane of Frankfort. Below the laryngeal prominence and applied perpendicularly along the neck axis. | 39.14      | 35.30      | 35.30    | 35.30      | 35.30   | 35.30 |
| Siganidaki, Q, et al.  | Brazil  | Cross-Sectional | Obesity  | 156    | 44.46    | 0             | 100              | Measuring tape       | Cross-cartilage      | 37.01      | 37.01      | 41.25    | 32.55      |         |       |
| Study Information | Neck Circumference (cm) |
|-------------------|------------------------|
| First Author      | Country               | Study Design | Disease | Sample | Mean Age | Men Proportion | Case Proportion | Instrument | Measured How | Cut Point (cm) | Cut Point for Men (cm) | Mean Overall | Mean Men | Mean Women | Mean Cases | Mean Controls | Prevalence Elevated Overall | Prevalence Elevated Men | Prevalence Elevated Women | Prevalence Elevated Cases | Prevalence Elevated Controls |
| Martinhos, F, et al. | Brazil | Cross-sectional | Obesity | 45 | 46.5 | 31.11 | 68.88 | Measuring tape | Orciod cartilage | 43.4 | 43.46 | 39.5 | 38.8 | 38.8 | 38 | 38 | 38 | 38 | 38 |
| Correa, M, et al. | Brazil | Cross-sectional | Obesity | 81 | 42 | 27.16 | 62.84 | Measuring tape | Orciod cartilage | 38.8 | 38.8 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 |
| Magalhaes, E, et al. | Brazil | Case-Control | Obesity | 88 | 49.2 | 21.6 | 78.4 | Measuring tape | Orciod cartilage | 43.4 | 43.46 | 39.5 | 38.8 | 38.8 | 38 | 38 | 38 | 38 | 38 |
| Miranda, G, et al. | Brazil | Cross-sectional | Obesity | 456 | 43.7 | 63.8 | 36.2 | Measuring tape | Orciod cartilage | 40 | 40.8 | 41.6 | 38.1 | 51.8 | 38.1 | 51.8 | 38.1 | 51.8 | 38.1 |
| Sakkas, P, et al. | Chile | Cohort | Stroke | 89 | 64.39 | 64 | 36 | Below larynx | - | 40 | 40.8 | 41.6 | 38.1 | 51.8 | 38.1 | 51.8 | 38.1 | 51.8 | 38.1 |
| Mendes, C, et al. | Brazil | Cohort | Obesity | 42 | 42.5 | 40.5 | 59.5 | Measuring tape | Orciod cartilage | 42.2 | 42.7 | 40.5 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 |
| Gorria, J, et al. | Mexico | Cohort | Cardiovascular disease | 112 | 55 | 34.51 | 65.49 | Measuring tape | Orciod cartilage | 39.31 | 37.4 | 38.93 | 37.4 | 38.93 | 37.4 | 38.93 | 37.4 | 38.93 | 37.4 |
| Lima, J, et al. | Brazil | Cohort | Obesity | 42 | 42.5 | 40.5 | 59.5 | Measuring tape | Orciod cartilage | 42.2 | 42.7 | 40.5 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 | 42.2 |
| Padilha, L, et al. | Brazil | Cross-sectional | Obesity | 20 | 48.54 | 0 | 100 | Landmarks | - | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 | 41.77 |
| Bruch, J, et al. | Brazil | Cross-sectional | Chronic Hepatitis C | 58 | 51.6 | 44.8 | 55.2 | Measuring tape | By the smallest circumference just above the laryngeal prominence with patient sitting down or standing up, with the spine erect and the head in the Frankfurt horizontal plane. | 37 | 34 | 37.3 | 34.6 | 40 | 37.3 | 34.6 | 40 | 37.3 | 34.6 | 40 |
| Sakkas, F, et al. | Chile | Cross-sectional | Obesity | 1464 | 54.4 | 65.23 | 34.77 | Measuring tape | Orciod cartilage | 40 | 41.6 | 43.2 | 38.2 | 41.6 | 38.2 | 41.6 | 38.2 | 41.6 | 38.2 |
| Oliveira, D, et al. | Brazil | Cross-sectional | Obesity | 60 | 36 | 25 | 75 | Measuring tape | Laryngeal prominence | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 |
| Venturin, M, et al. | Brazil | Cross-sectional | Epilepsy | 98 | 35.97 | 60.2 | 39.8 | Measuring tape | Laryngeal prominence | 39 | 35 | 34.06 | 33.71 | 34.41 | 34.06 | 33.71 | 34.41 | 34.06 | 33.71 | 34.41 |
| Barros, L, et al. | Brazil | Cross-sectional | Obesity | 14 | 46.8 | 14.3 | 85.7 | Measuring tape | Laryngeal prominence | 43 | 41 | 41.3 | 41.3 | 41.3 | 41.3 | 41.3 | 41.3 | 41.3 | 41.3 |
| Gallegos, C, et al. | Argentina | Cross-sectional | Obesity | 22 | 61 | 86.37 | 13.63 | Measuring tape | Laryngeal prominence | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 | 44.5 |
| Strafin, R, et al. | Brazil | Cross-sectional | Obesity | 120 | XXX | 24 | 76 | Measuring tape | Laryngeal prominence | 44.29 | 51.5 | 42 | 44.29 | 51.5 | 42 | 44.29 | 51.5 | 42 | 44.29 |
| Orel, S, et al. | Mexico | Cross-sectional | Obesity | 21 | XXX | 28.58 | 71.42 | Measuring tape | Laryngeal prominence | 44.41 | 47.7 | 43.1 | 44.41 | 47.7 | 43.1 | 44.41 | 47.7 | 43.1 | 44.41 |
Table 4. Summary table about risk of bias for cross-sectional studies.

| First Author       | External Validity |   |   |   | Internal Validity     |   |   |
|--------------------|-------------------|---|---|---|-----------------------|---|---|
|                    | 1. A close        | 2. True or close | 3. Random | 4. Non-response bias | 5. Directly from the | 6. Acceptable | 7. Measured | 8. Same mode | 9. Length of | 10. Numerator(s) and |
|                    | representation    | representation  | selection | minimal            | subjects             | case definition   | was reliability and validity | mode of data | the shortest | denominator(s) | appropriate |
|                    |                   |               |           |                   |                      |                |                       | collection    | prevalence   |                          |            |
| Moraes, W. et al.  | NO                | YES           | YES       | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | LOW        |
| Neves, T. et al.   | NO                | UNCLAR        | UNCLAR    | NO                | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Ribeiro, L. et al. | NO                | YES           | YES       | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | LOW        |
| Méndez, B. et al.  | YES               | YES           | YES       | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | LOW        |
| Leite, J. et al.   | NO                | YES           | YES       | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | LOW        |
| Tavares, C. et al. | NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | MODERATE   |
| Dantas, E. et al.  | NO                | NO            | NO        | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| De Siqueira, K. et | NO                | YES           | YES       | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | LOW        |
| De Alexandria, F.  | NO                | NO            | NO        | NO                | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Alves, H. et al.   | NO                | YES           | YES       | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | LOW        |
| Santos, D. et al.  | NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | MODERATE   |
| Pedreros, A. et al.| NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | UNCLEAR              | YES          | YES          | YES          | MODERATE   |
| Hauser, M. et al.  | NO                | UNCLAR        | UNCLAR    | NO                | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Noqueira, M. et al.| NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Barbosa, P. et al. | NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Frizon, V. et al.  | NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Coelho, H. et al.  | NO                | NO            | NO        | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| Da Silva, A. et al.| NO                | UNCLAR        | UNCLAR    | YES               | YES                  | NA              | YES                  | YES          | YES          | YES          | MODERATE   |
| First Author | Risk of Bias – Prevalence Studies |
|--------------|----------------------------------|
| Zonato, A.   | 1. A close representation        |
|              | 2. True or close representation  |
|              | 3. Random selection              |
|              | 4. Non-response bias minimal      |
|              | 5. Directly from the subjects    |
|              | 6. Acceptable case definition    |
|              | 7. Measured reliability and validity |
|              | 8. Same mode of data collection  |
|              | 9. Length of the shortest period |
|              | 10. Numerator(s) and denominator(s) appropriate |
|              | 11. Summary                       |
|              | Zonato, A. et al. NO               |
|              | Sutherland, K. et al. NO          |
|              | Pinto, J. et al. NO               |
|              | Oliveira, N. et al. NO            |
|              | Sabat, M. et al. NO               |
|              | Souza, F. et al. NO               |
|              | Boemmel, L. et al. NO             |
|              | Hiraj, M. et al. NO               |
|              | Borges, P. et al. NO              |
|              | Saldivia, R. et al. NO            |
|              | Jorquera, A. et al. NO            |
|              | Rodrigues, A. et al. NO           |
|              | Aguiar, I. et al. NO              |
|              | Saldivia, P. et al. NO            |
|              | Chávez, C. et al. NO              |
|              | De Menezes, R. et al. NO          |

**External Validity**

- NO
- UNCLAR
- YES
- NA
- UNCLEAR
- MODERATE
- YES
- YES
- YES
- MODERATE
| First Author                  | External Validity | Internal Validity | 11. Summary |
|------------------------------|-------------------|-------------------|-------------|
| Faria, N. et al.             | NO                | UNCLEAR           | MODERATE    |
| Schommer, V. et al.         | NO                | UNCLEAR           | MODERATE    |
| Amaro, T. et al.            | NO                | UNCLEAR           | MODERATE    |
| Volacho, A. et al.          | NO                | NO                | LOW         |
| Stabe, C. et al.            | YES               | NO                | LOW         |
| Zununcio, V. et al.         | NO                | NO                | LOW         |
| Chaves, T. et al.           | NO                | YES               | MODERATE    |
| Alfie, J. et al.            | YES               | YES               | LOW         |
| Soares, M. et al.           | NO                | YES               | LOW         |
| Ruiz, A. et al.             | NO                | YES               | LOW         |
| Polesel, D. et al.          | NO                | YES               | LOW         |
| Mora, R. et al.             | YES               | YES               | LOW         |
| Closs, V. et al.            | NO                | UNCLEAR           | LOW         |
| Petreça, D. et al.          | NO                | NO                | MODERATE    |
| Peralta, C. et al.          | NO                | YES               | MODERATE    |
| Dos reis, E. et al.         | NO                | YES               | MODERATE    |
| Ferreira, A. et al.         | NO                | YES               | LOW         |
| Ramires, A. et al.          | NO                | UNCLEAR           | MODERATE    |
| Mora, R. et al.             | NO                | UNCLEAR           | MODERATE    |
| First Author | 1. A close representation | 2. True or close representation | 3. Random selection | 4. Non-response bias minimal | 5. Directly from the subjects | 6. Acceptable case definition | 7. Measured was reliability and validity | 8. Same mode of data collection | 9. Length of the shortest prevalence period | 10. Numerator(s) and denominator(s) appropriate | 11. Summary |
|--------------|--------------------------|-------------------------------|-------------------|-----------------------------|-----------------------------|--------------------------------|---------------------------------|-------------------------------|---------------------------------|---------------------------------|-----------------------------|
| Sgariboldi, D. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Nerbass, F. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Lucas, E. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Freire, L. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Sgariboldi, D. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Martinho, F. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Correa, M. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Menezes, D. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Miño, F. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Padilha, L. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Bruch, J. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Saldias, F. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Oliveira, D. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Venturi, M. et al. | NO | UNCLEAR | YES | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Barbosa, L. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | YES | YES | YES | YES | YES | MODERATE |
| Gallego, C. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Serafim, P. et al. | NO | UNCLEAR | UNCLEAR | NO | YES | NA | NO | YES | YES | YES | YES | MODERATE |
| Oriol, S. et al. | NO | UNCLEAR | UNCLEAR | YES | YES | NA | NO | YES | YES | YES | YES | MODERATE |
Table 5. Summary table about risk of bias for case-control studies.

| First Author               | Selection | Comparability | Exposure |
|---------------------------|-----------|---------------|----------|
| Genta, P. et al.          | A         | A             | A        |
| De Paiva, R. et al.       | A         | A             | A        |
| De Castro, J. et al.      | A         | A             | A        |
| Castorena-Maldonado, A. et al. | A   | A             | A        |
| Cunha, F. et al.          | A         | A             | A        |
| Magalhaes, E. et al.      | A         | A             | A        |
| Saldias, P. et al.        | A         | A             | A        |
| First Author            | Selection                                                                 | Comparability | Exposure | Risk of Bias - Cohort Studies | Outcome of the Exposed Cohort | Outcome of the Non-Exposed Cohort |
|------------------------|---------------------------------------------------------------------------|---------------|----------|--------------------------------|-------------------------------|----------------------------------|
| Moura, P. et al.       | Unclear                                                                   | NA            | NA       | NA                            | NA                            | NA                               |
| De Castro, J. et al.   | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |
| Prescinotto, R. et al. | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |
| Mendes, C. et al.      | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |
| Garcia, J. et al.      | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |
| Lima, J. et al.        | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |
| Pizarro-Montaner.      | NA                                                                        | NA            | NA       | NA                            | NA                            | NA                               |

Table 6: Summary table about risk of bias for cohort studies.
Results in context
NC has been associated with several cardiometabolic risk factors: insulin resistance, elevated cholesterol, triglycerides, LDL-cholesterol and obesity. Moreover, NC has also been associated with SAHOS. Nevertheless, and despite that NC appears to be as good (or even better) as other anthropometric indicators (e.g., BMI), NC has not been subject to extensive research. In this work we propose the first systematic review and meta-analysis to reveal the overall mean NC in LAC, and to highlight research needs. Our work is the starting point to raise awareness about NC as a potential anthropometric indicator, while signaling the need for NC cut-off points in LAC.

A multinational study (ELANS conducted in 2014–2015) was conducted in eight LAC countries and they found a mean NC of 35.60cm, which is virtually the same as our pooled mean estimate. This similarity could be explained by the fact that we covered the same countries. Notably, the ELANS study included populations in more countries than those herein summarized, yet we included older and more recent studies, and we also summarized evidence from a larger sample. Overall, mean NC in LAC appears to be ~35cm, though this deserves further verification following consistent methods and including countries for which evidence is still unavailable.

Studies in Asia reported a mean NC between 31cm and 44cm. Our pooled estimates fall within this range. As it is the case with other anthropometric indicators (e.g., BMI), LAC is usually in the middle of the distribution. Reasons behind this could be diet and nutrition, phenotypes, opportunities to exercise, and access to preventive healthcare, all of which vary widely across countries and regions. As more evidence about NC in LAC becomes available, we would be in a stronger position to study determinants and outcomes for high NC to identify reasons for cross-country and cross-region comparisons.

The mean NC and prevalence of high NC was larger in captive populations in comparison to the general population. This could be explained by the underlying profile of each captive group. For example, in bus drives, miners, sedentary women and adults - elderly waiting for medical attention, those variables were higher due to the fact that these people have a long working day which could condition a sedentary lifestyle. However, in other population groups (e.g., university students, health professionals, outdoor gym users) the mean NC and prevalence of high NC was lower than in the general population. This could be because those groups have healthier lifestyles and are more concerned about their health (due to their profession).

We also found that the mean NC in the group of OSAH and obese is higher than the general population (41.09cm and 42.56cm vs 35.69cm). This is concordant with the studies that considered NC as an anthropometric measure useful for assessing the risk and severity of OSAH and also it is known for its strong relationship with obesity. A higher NC in this group of patients can be explained by the accumulation of fat around the neck contributing to the airway narrowing and at the same time facilitating its obstruction. NC could be incorporated as part of the standard of care for OSAH patients.

Currently, there are no guides that include NC as an official anthropometric measure; however, there are studies that found NC as a reliable index and highlight the fact that it is an economical test easy to use which takes less time and correlates well with other anthropometric parameters such as BMI, WC and hip circumference. Our findings indicate that NC could be used either in clinical practice and epidemiologic studies.

Conclusions
In this systematic review and meta-analysis, the mean NC in LAC was 35cm in the general population; although there were different thresholds, the prevalence of high NC ranged between 37.00% and 57.69%. The methodology to measure NC was inconsistently reported and evidence lacks from several countries in LAC. Even though NC could be a novel anthropometric indicator closely related with different diseases and health outcomes, NC has been seriously understudied in LAC. This work highlights the current evidence about NC in LAC and pinpoints research gaps.

Data availability
Underlying data
All data underlying the results are available as part of the article and no additional source data are required.

Extended data
Figshare: Supplementary Material. https://doi.org/10.6084/m9.figshare.1355053

This project contains the following extended data:
- Supplementary Material.docx (Document with study search strategy)

Reporting guidelines
Figshare: PRISMA checklist for ‘Neck circumference in Latin America and the Caribbean: A systematic review and meta-analysis’ https://doi.org/10.6084/m9.figshare.1355053
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This is an interesting article that reviews the little-used measurement of neck circumference and the advantages and limitations of this measure as reported in the literature. The review of the use in different studies is helpful and the authors suggest that it would be a convenient and useful addition to the arsenal of anthropometric measures currently in use. The review and suggestion for the use of measuring neck circumference is convincing as the neck is relatively accessible for measurement and this could be a useful addition in studies that require anthropometry.

I recommend indexing.

**Are the rationale for, and objectives of, the Systematic Review clearly stated?**
Yes

**Are sufficient details of the methods and analysis provided to allow replication by others?**
Yes

**Is the statistical analysis and its interpretation appropriate?**
Yes

**Are the conclusions drawn adequately supported by the results presented in the review?**
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Population research which usually includes anthropometric assessment of candidates for randomized controlled studies

I confirm that I have read this submission and believe that I have an appropriate level of
expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 02 February 2021

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The increase in neck circumference, a measure of ectopic fat, is associated with higher cardiometabolic risk and obstructive sleep apnea beyond classical anthropometric measures of obesity.

The authors performed a systematic review and meta-analysis to estimate the mean neck circumference and the prevalence of high neck circumference in Latin America and the Caribbean. I find the article correctly written and analyzed.

Although the measurement of neck circumference differs between studies, the net impact of these differences is probably minimal compared to different definitions of abdominal obesity. This, added to the fact that to measure the circumference of the neck it is not necessary to ask the patient to get up from the chair or to remove their clothes, it represents advantages over other anthropometric measurements.

The objective of the study was to establish mean values and the prevalence of high neck circumference in Latin America and the Caribbean. This was based on statistical definitions provided by the selected studies. Another approach to define normality and cutoff values could be based on the consequences of increased neck circumference on metabolism, blood pressure, and obstructive sleep apnea.

Are the rationale for, and objectives of, the Systematic Review clearly stated?
Yes

Are sufficient details of the methods and analysis provided to allow replication by others?
Yes

Is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results presented in the review?
Yes

Competing Interests: No competing interests were disclosed.
**Reviewer Expertise:** My area of expertise is high blood pressure. I am the first author of one of the articles selected in the current metaanalysis (25).

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.