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REVIEW ARTICLE

Alteration in Peripheral Muscle Strength among Overweight and Obese Individuals: A Systematic Review

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Abstract:

Peripheral muscle dysfunction in Overweight (OW) and Obesity (OB) leads to fatigue and activity limitations. However, there are contradictory views regarding the exact level with regard to hand grip and quadriceps muscle strength in OW and OB. The main objective of the present systematic review was to synthesize the literature for the strength part of the hand grip and quadriceps muscle strength among OW and OB. Literature search of Scopus, EBSCO and PubMed databases from 01.01.2004 to 30.06.2016, was performed. We set our search strategy using the terms "overweight OR obesity" AND "muscle strength" AND "grip OR quadriceps". Two reviewers administered established eligible criteria and extracted the data. Strengthening the Reporting of Observational studies in Epidemiology (STROBE) was used to assess the risk of bias. Sixteen articles which were included identified Handgrip Strength (HGS), shoulder flexor, elbow flexor and knee extensor were found to be altered. There were consistent results with an increase in quadriceps muscle strength, whereas differed results were found in hand grip to increase and decrease in muscle strength in the presence of OW and OB. It is concluded that HGS appeared to be diversified with findings of increased and decrease strength, whereas regarding the quadriceps muscles, the findings were homogeneous.

Keywords: Overweight; Obesity; Muscle Strength; Grip; Quadriceps

Introduction:

Over the past few decades, the prevalence of Overweight (OW) and Obesity (OB) has increased substantially. OW and OB are defined as abnormal or excessive fat accumulation that may impair health [1]. OW and OB are considered to be one of the most serious health issue consequences in the 21st century [1]. Identification of potential problems and analysis of health issues in OW and OB were proposed as one of the approaches for setting priority areas of action. Respiratory dysfunction, cardiovascular disease, cancer, musculoskeletal dysfunctions are commonly observed in the affected population [2].

According to the Centre for Disease Control, United States, 31% of adults with OB reported a diagnosis of musculoskeletal disorder compared to only 16% of Non-Obese (NO) individuals [3]. OB was implicated in the progression of a wide variety of musculoskeletal conditions and impairment [3-8] . Disproportionate weight can seriously affect the growth and health of bones, joints, and muscles, especially during childhood and adulthood, which places excess stress on the growth plate. This can lead to early arthritis, a greater risk of bone fractures, and other serious complications [8]. There is a high prevalence of pain in the neck (10-19%), shoulder (18-26%), elbow (8-12%) and hand (9-17%) in OB, which has consistently become a significant risk factor for skeletal muscle weakness [3,9].

Previous research studies showed fatty infiltration and alteration in the distribution of the muscle fibre in OB and OW [10-12]. This strength property varies, thereby the physical capabilities are compromised which eventually leads to fatigue and functional limitations. A recent study suggested that an individual with OB may predispose to abnormal gait pattern as because of weakness and susceptibility to fatigue in lower limb muscles [13]. This could predispose to musculoskeletal injury and other pathology related to the muscle.

The shoulder flexors, abductors, elbow extensors and Handgrip Strength (HGS) are compromised in OW and OB. HGS was found to be affected and this constituent was assessed through different types of handheld dynamometer [14]. On the other hand, regarding the lower limb, hip flexors, knee flexors and knee extensors were also compromised and these muscles were assessed through outcome measures such as isokinetic dynamometer and other types of dynamometers.

Since obesity could predispose to musculoskeletal injury, there is an increased chance of developing osteoarthritis. Therefore proper knowledge with relation to muscular strength is important for devising appropriate rehabilitation measures. In this context, the present review intended to identify the impact on muscle strength of both upper and lower limb related to the musculoskeletal system in OW and OB individuals. It is important to know which muscles are most commonly affected in OW and OB.

The aim of the present review was to observe the exact impact on upper and lower limb muscles especially with regard to hand grip and quadriceps muscle strength in OW and OB individuals. In addition, the present review also focussed on the protocol and outcome measures used to test these muscles. The impact of the peripheral muscles, outcome measures used and its protocols were examined in this review.

Materials and Methods:

Literature Search Strategy

We performed a comprehensive literature search for muscle dysfunction in subjects with OW and OB by searching electronic databases such as PubMed, Scopus, and EBSCO for relevant articles published from 01.01.2004 until 30.06.2016. We set our search strategy to the combined search of #1 (overweight OR obesity) AND #2 (muscle strength) AND #3 (grip OR quadriceps). There were language and category restrictions during databases searching. Only those articles published in English were examined. In addition, we have contacted the experts in the field of obesity as recommended by earlier guidelines to identify relevant articles [15].

Inclusion and Exclusion Criteria

The title and abstract of studies identified by the search were screened for potential relevance. The full text of all potentially relevant studies was reviewed in order to decide the eligibility criteria. We included studies that described the peripheral muscle strength measurement of upper and lower limb muscles. Authors independently screened the results of the electronic searches to select the potentially relevant title and abstract according to the criteria defined in this study. Literature such as cross-sectional trials and comparative study designs were included. Retrospective studies, abstracts, letters to editors, conference abstracts and animal studies were excluded. The age range was kept between 19 - 65 years, and the rest were excluded.

Data Extraction

Two authors (VM and NFHAR) extracted data individually using an MS-Word structured data extraction form specially created for this review. The extracted data were compared and discussed by two authors before being compiled as final information. Information extracted from each article included: i) name of the studied muscle, ii) equipment used to measure muscle function, iii) the sample population, iv) main results.

Validity Assessment

Two authors (VM and NFMY) analyzed the data extracted from the potentially relevant articles. Following analysis, it was decided to depend on information extracted from the most relevant studies; those that were organized with proper data presentation, clearly verified selection of protocols, and demonstration of research methods to reduce the risk of bias. All the included studies were assessed independently by two reviewers using the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist and the details of the reporting are presented in Table 1 [16]. The data were not suitable for statistical pooling because of heterogeneity of the study designs. Therefore, the results were summarized, qualitatively. The STROBE scores were agreed between the authors.

Quantitative Data Synthesis

There was significant muscle dysfunction in OB and OW studies which were observed classically in the upper and lower limb muscles. The study results were presented in the form of tables (Table 2 & 3).

Table 1: Table showing Risk of Bias (STROBE) Assessment of the Included Studies

	Reference Numbers as Per the Alphabetical order of Author															
STROBE	[28]	[23]	[20]	[21]	[26]	[19]	[27]	[29]	[10]	[25]	[31]	[24]	[17]	[30]	[18]	[22]
1a	-	+	-	-	+	-	-	-	-	+	+	+	-	-	-	-
1b	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
4	-	+	-	-	+	-	-	+	-	+	+	+	+	+	-	+
5	+	+	+	+	+	+	+	-	+	+	+	+	-	-	-	+
6a	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6b	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Continued...

	Reference Numbers as Per the Alphabetical Order of Author															
STROBE	[28]	[23]	[20]	[21]	[26]	[19]	[27]	[29]	[10]	[25]	[31]	[24]	[17]	[30]	[18]	[22]
11	-	+	+	+	+	+	+	-	-	-	-	-	+	-	+	+
12a	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12b	+	+	+	+	+	-	-	-	+	+	+	+	-	-	-	-
12c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
12d	+	+	+	+	-	+	+	-	+	+	+	+	+	-	-	+
12e	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
13a	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13b	*	*	*	*	-	*	*	*	*	*	*	*	*	-	-	+
13c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
14a	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14c	*	*	*	*	+	*	*	*	*	*	*	*	*	*	*	*
15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
16a	-	-	+	+	+	-	-	-	+	-	-	+	-	-	-	-
16b	-	+	+	+	+	+	-	-	+	-	-	+	-	-	-	-
16c	*	*	*	*	+	*	*	*	*	*	*	*	*	*	*	*
17	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
19	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+
20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
22	-	+	-	-	+	-	+	+	+	+	-	+	-	+	-	+
Total (+)	17	23	20	20	27	18	19	16	21	21	20	23	18	17	17	23
Total STROBE (%)	57	77	67	67	82	60	63	53	70	70	67	77	60	57	57	74

*STROBE – Strengthening the Reporting of Observational Studies in Epidemiology; * – Not applicable*

Table 2: Table showing an Overview of Peripheral Muscle Function of Upper Limb

Author and year of publication	Setting	Sample size/BMI (mean±SD) kg/m²	Upper limb muscles	Outcome measure-Protocol	Results	p -value
Pescatello *et al.* (2007) [10]	Multicentre: Ireland, USA	NW : 449 (22.0 ±0.1) OW & OB : 238 (29.2 ±0.2)	Elbow flexor	Custom-made preacher bench & standard preacher curl bench – MVC of non-dominant elbow flexor was measured.	Pre and post -MVC was greater in OW &OB than NW of isometric strength and dynamic strength.	p <0.05
Shin *et al.* (2014) [17]	Seoul	OW & OB 97(30.3±3.8)	HGS	Lafayette Instrument hand dynamometer – Held with the hand of one of the arms stretched out to the side of the body at 45°angle & squeezed the handgrip as hard as possible.	Higher lean mass related to better physical performance including HGS.	p <0.05
So *et al.* (2014) [18]	Japan	OW & OB 28(30.3 ±3.5) 12: DA 16: DAA	HGS	Hand dynamometer – Measured in both hands	Hand-grip improved significantly only in DAA group.	p =0.06
Lad *et al.* (2013) [19]	India	UW : 60 (16.62 ±2.79) NW : 60 (15.85 ±2.61) OW : 60 (26.22 ±2.18)	HGS	Handgrip dynamometer – advised keeping their hand on a table with the angle in the elbow being maintained at 90°and were asked to press the handle.	In male, HGS was greater in NW than OW & UW whereas, for female, HGS was greater in UW than NW & OW.	p >0.05
Cavuoto (2013a) [20]	USA	NOBY : 8 (22.7 ±1.8) NONO : 8 (34.1 ±2.8) OBY : 8 (24.4 ±0.9) OBO : 8 (36.4 ±3.3)	Shoulder flexor	Commercial dynamometer (Biodex)– Maintaining the upper arm against padded fixture, participants were asked to progressively build to a maximum exertion	Shoulder muscle strength was higher in OB.	p =0.04

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Cavuoto *et al.* (2013b) [21]	USA	OB : 18 (22.5 ±1.8) NOB : 18 (33.6 ±3.1)	HGS, shoulder flexor & trunk extensor	Computerized grip dynamometer – Seated with upper arm at their side, elbow flexed 90°& wrist in neutral position commercial dynamometer (Biodex) - Measurement of shoulder flexion in sitting with their back inclined	OB had an overall higher absolute strength but lower relative strength.	p =0.00
Tibana *et al.* (2013) [22]	Brazil	OW : 9 OB : 5 (29.6 ±4.1)	HGS	Manual mechanical dynamometer–arms extended and forearm positioned in neutral position.	Isometric HGS improved after 8 weeks of RT program.	p =0.02
Carneiro *et al.* (2012) [23]	Brazil	EU : 16 (23.4 ±1.6) OB : 15 (33.5 ±3.0)	HGS	Jamar hand-held dynamometer–Followed American Society of Hand Therapists protocol. Average of three trials was recorded.	No differences in HGS between the two groups.	p =0.84
Sallinen *et al.* (2010) [24]	Finland	M: 1084 (27.6 ±4) F: 1562 (28.1 ±4.7)	HGS	Hand-held dynamometer– Measurement performed with the dominant hand with the participant in seated position with the elbow flexed at 110°.	HGS by BMI interaction on mobility limitation was increased significantly among men while no such interaction was observed among women.	M, p = 0.02 F, p = 0.15
Ravisankar *et al.* (2005) [25]	India	UW : 74 (16.6 ±1.3) NW : 47 (20.2 ±1.7) OW : 24 (30.5 ±6)	HGS	Handgrip dynamometer–MVC sustained at least for 3 seconds.	HGS significantly different between the groups	p = 0.06
Jung *et al.* (2016) [26]	Japan	n = 283 (23.6 ±3.3)	HGS	Hand-held dynamometer – performed 2 trials with each hands alternately in standing position with arms hanging naturally.	Obesity was associated with low muscle weakness with the incidence of mobility limitation.	p = 0.043

M - Male; F - Female; OB - Obese; OW - Overweight; UW - Underweight; NW - Normal Weight; HGS - Handgrip Strength; NOBY - Non-obese Young; NONO - Non-obese Old; OBY - Obese Young; OBO - Obese Old; NOB - Non-obese; EU - Eutrophic; DA - Diet & Aerobic; DAA - Diet, Aerobic exercise & Acceleration; RT - Resistance Training; BMI - Body Mass Index; MVC - Maximal Voluntary Contraction.

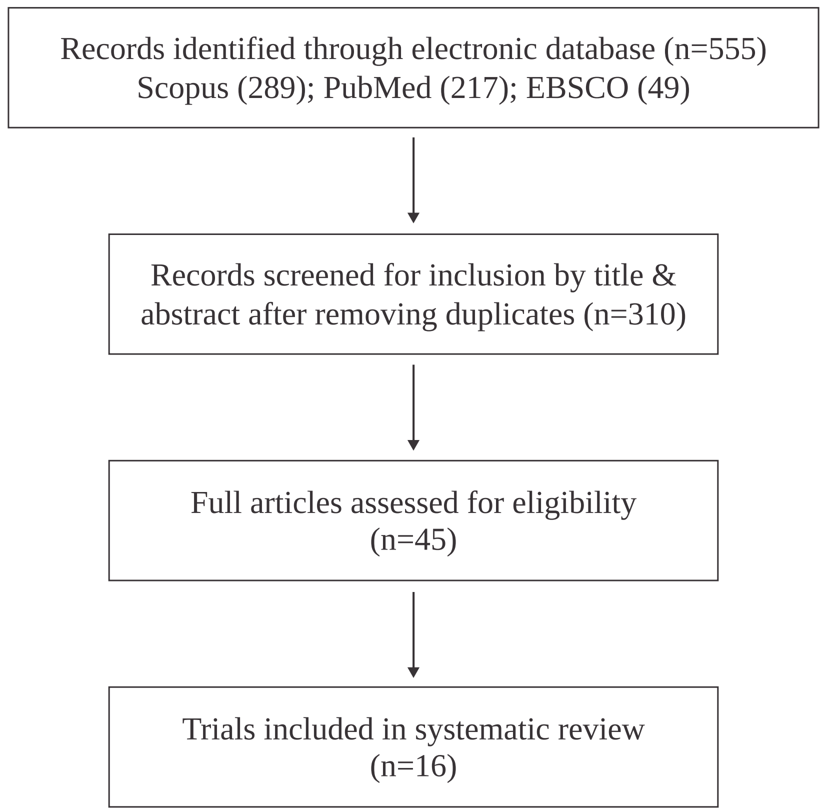

Fig. 1: The Flowchart to show the Process of Selecting Potential Studies.

Results:

Flow of Included Study

The comprehensive literature search yielded a total of 16 articles (Fig. 1). Of these, 11 met the inclusion criteria as an upper limb function, 4 met as lower limb function, 1 met both upper and lower limb function and the remaining articles were excluded as they did not meet the objective of the study.

Study Characteristics

Among 16 relevant articles, 11 studies focussed on the upper limb muscle function [10, 17-26], whereas only four studies investigated the lower limb muscle function [27-30]. On the other hand, only one study evaluated the impact of both upper limb and lower limb muscles [31].

Table 2, depicted the collective information of 11 articles which were related to the peripheral muscle strength of upper limbs. In the majority of the articles, HGS was used as one of the predictors of upper limb muscle dysfunction in OW and OB population [17, 18, 20-22, 24-26] while the remaining studies had an impact on shoulder flexor [20] and elbow flexor muscles [10]. In general, HGS was found to be decreased in OW and OB populations [19, 25]. The variables remain unchanged in only one of the included study [23]. However, there were studies which reported to have greater upper limb muscle strength in OW and OB population compared to the Underweight (UW) and Normal Weight (NW) [10, 18, 20-24].

Table 3: Table showing An Overview of Peripheral Muscle Function of the Lower Limb

Author and year of publication	Setting	Sample size/BMI (mean±SD) kg/m^2	Upper limb muscles	Outcome measure-Protocol	Results	p -value
Lazzer *et al.* (2013) [27]	Italy	NW : 10 OB : 11 (43.2±5.4)	KE	Mechanical braked cycle ergometer & custom-built knee extension ergometer – subjects pushed on a padded bar attached to a lever arm extending the lower part of the right leg	Higher maximal isometric force of KE muscle was found in OB	p <0.00
Capodaglio *et al.* (2009) [28]	Italy	PWS : 6 (45.8±4.4) NW : 14 (21±1.6) OB : 20 (38.1±3.1)	KF & KE	Isokinetic dynamometer (Cybex Norm) – Measured in both limbs with the subject in a sitting position with help flexed at 90°	OB showed significantly higher strength compared to healthy for KE muscle.	p =0.00
Maffiuletti *et al.* (2008) [29]	New Zealand	NOB : 10 (19±1) SOB : 10 (34±3)	Quadriceps	Isokinetic dynamometer – Involved 3-4 consecutive knee extension performed at an angular velocity of 180°/s	Greater absolute isokinetic & isometric torque in OB	Isokinetic p = 0.032 Isometric p = 0.00
Siriphorn *et al.* (2014) [30]	Thailand	OW : 16 (24.15±0.50) (24.15±0.50)	Hip flexor/ extensor Hip adductor/ adductor KE/KF Ankle DF/PF	Hand held dynamometer – Testing sequence began in sitting and progressed to supine, side and prone lying position	Lower limb muscle strength increased among OW	p = 0.00

DF - Dorsiflexion; PF - Plantar Flexion; OB - Obese; OW - Overweight; NW - Normal Weight; PWS - Prader Willis Syndrome; NOB - Non-obese; SOB - Severely Obese; KE - Knee Extensor; KF - Knee Flexor; HGS - Handgrip Strength.

Therefore, it can be inferred that as the BMI increases, the HGS was also higher [19, 24]. Apart from HGS, shoulder and elbow flexors were also found to be higher in OB [10, 20]. In contrast to those study results, earlier studies reported HGS higher among UW and NW compared to the OB individual [19, 25].

The majority of the studies explored solely the absolute strength of the peripheral muscle and only one of the study reported both absolute and relative strength. In this perspective, it was found that OB had an overall higher HGS, shoulder flexor and trunk extensor for absolute strength and lower when it was accounted to relative strength [21].

In relation to the lower limb, according to the objective of the study, quadriceps femoris was shown to be another good indicator to decide the peripheral muscle function as depicted in Table 2. All the four included studies for the lower limb showed greater lower limb strength. However, there were no contradictory results in the lower limb strength compared to the upper limb [27-30]. Assessment of both upper and lower limb strength was seen in only one study in which it was assumed that only Knee Extensor (KE) strength was found to be greater, whereas there were no changes in HGS between OB, NW and UW individuals [31].

Collectively, the results of this systematic review suggest that most commonly affected and studied muscle among OW and OB, was HGS and quadriceps muscle.

Discussion:

This review summarized the findings of the effect of peripheral muscle function in both upper and lower limb in OW and OB subjects. The results of the study showed that HGS was used as one of the outcome measures to investigate the impact of upper limb muscle function. It was found that quadriceps muscle strength was tested for lower limb muscle function. From these findings, it is inferred that HGS and the quadriceps are the common muscles studied to measure the strength of OW and OB subjects.

Current evidence shows OB related dysfunctions which were reported for both upper and lower limb muscles, were for HGS, shoulder flexors, elbow extensors and quadriceps muscle strength [10, 17-31]. The evidence for HGS appeared to be diversified with findings of increased [21] and decreased [19, 25] strength, whereas regarding the lower limb, the findings were homogeneous [27-30].

Even though majority of the studies addressed greater strength in both upper and lower limbs in specific to HGS, shoulder flexors, elbow extensors and quadriceps muscle strength, these results finally gave the impression of reduction after corrected for Fat-Free Mass (FFM) [32]. In general, the strength constituent can be divided into absolute and relative strength. Absolute strength can be compared with no concern to body size while relative strength is normalized with body mass and FFM [32, 33]. Among these included studies, few used absolute muscle strength in which the strength part was proved to be higher in both upper and lower limbs [10, 20, 29] whereas relative component seemed to be reduced in the strength constituent of the muscle in two of the included studies [21, 32]. From these studies, it could be inferred that relative strength was more suitable and it was reduced.

An earlier study settled the increase in muscle strength to be credited to the bulk of the muscle and this was accounted with greater Maximal Voluntary Contraction (MVC) in elbow flexor among OB individuals who were predisposed to have the greater absolute muscle strength of the biceps [10]. Besides, the resultant reduced relative strength could be due to damaged muscle capacity [32], differences in muscle fibre type and metabolic function [34, 35] or an inability to achieve full motor unit activation [36]. Implications for a lower strength capacity may include poor performance on higher complexity tasks needed at work, particularly for tasks involving manual material handling.

The muscle which is expected to undergo decline among OB is in the lower limb, as this is important for postural control, whereas the upper limb muscles are considered as executive muscle as they are less often recruited for support of body segment [33]. However, the included studies in our review article showed that lower limb muscles were less often studied compared to the upper limb muscles. From these results , it could be inferred that the lower limb muscles, which are considered as locomotor muscles, need to be studied extensively in future studies in order to know the impact.

With respect to methodological perspective, the choice of outcome measure used for strength measurement differed as different protocols were considered in these studies. Nevertheless, all these studies agreed that HGS may be fulfilled to be as a measurement tool in assessing the peripheral muscle function of the upper limb whereas quadriceps muscle is considered for the lower limb. We also conclude that the studies which used different techniques in analyzing the muscle strength could lead to conflicting results. The analysis of the upper and lower limb strength, indeed have utilized dominant as well as non-dominant limb with different elbow and leg positions [37, 38].

Jamar and isokinetic dynamometer are considered to be a reliable and valid tool to measure the strength aspect of a muscle [39, 40]. Even though, the recruited studies in this review utilized these equipment's, the protocol differed between the studies which made us imply different study findings. The most protocol, which were commonly used for the determining HGS was adapted from the American Society of Hand Therapists (ASHT) [41, 42]. Apart from this dynamometer, an earlier study specially developed dynamometer and manual dynamometer for assessing HGS [43]. The results of the study found that those subjects who underwent exercise program had greater HGS using specialized dynamometer. However, the validity and reliability of the equipment used in the study were not known. Similarly, whether studies followed recommended guidelines, were also not spelled specifically in the recruited studies. Therefore, it could be recommended to follow universal guidelines or protocols to generalize the study results and this was not observed in the extant search of the literature.

As there were studies which reported on how the OB influences the muscle function, it will be of interest to know the reasons which contribute to the change in skeletal muscle structure and function. It was believed that OB people have fewer fatigue resistant because of the lower percentage of type I fibres and a higher percentage of type II muscle fibres in their skeletal muscle [10-12, 27, 44, 45]. Besides, there was evidence stating the increasing of fat infiltration or intramyocellular fat and fascicle strength may also alter the muscle strength in OB people as proved in earlier studies which are being associated with low calf muscle strength and power [46-49]. In conjunction with these contributing factors, the muscle function was believed to be altered in most of these OB individuals. Lower limb muscle mass which contributes to muscle function is closely related to metabolic parameters among the obese population and this region is considered as most important as compared to upper limb muscles [50].

This systematic review encompasses several important points, including its distinctiveness. So far, this is one of the imperative reviews which suggest to repossess, analyze and critically appraise the most commonly affected muscles in this special population. There are nevertheless few limitations in this study which can account for different characteristics of the subjects included in the studies with different methods. The included studies were carried out in different geographical areas examining the variety of races. Therefore, the information retrieved in this review was restricted to a certain race and country but not as an entire one and the findings could not be generalized. In fact, there was lack of studies carried out in one particular geographical area. Therefore, it is difficult to infer whether these subjects among different geographic zones had a similar impact or not.

Based on the included articles, Brazil, the United States and Italy were found to be the countries which had at least two published literature in this field. In brief, the finding of this review was limited to certain populations and zones.

Overall, the information documented in this review article may be applied as a useful tool to examine the HGS and quadriceps muscle strength among OW and OB subjects. Hence, it can be conceived as a new knowledge 'innovation' in this specialized field and the clinical application of the results can be enhanced further by research process. Hence, further research work is necessary to ascertain the role of HGS and quadriceps muscles, especially with unique methodological measures. Studies are to be necessitated with different geographical areas to generalize the study findings.

Conclusion:

The results of this systematic review revealed that the HGS and quadriceps strength were the most commonly affected and studied muscles in OW and OB population. The results of the strength constituent of the HGS were found to be varied with increase and decrease in strength and with regard to the quadriceps, it was increased. This could be due to wide variation in the device and protocols used with different study settings and regions. We suggest that in future, the rehabilitation of OW and OB subjects may focus on individual muscles to alter the strength properties and to reduce weight thereby reducing the fatigue.

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