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Range of motion limitations of the upper body in obese female workers

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Key words: Obese female workers; functional limitation; biomechanics; ergonomy

Parole chiave: Lavoratrici obese; limitazione funzionale; biomeccanica; ergonomia

Summary

Background: *The prevalence of obesity is increasing worldwide, and the economic consequences of an increased percentage of obese workers are relevant in terms of health costs and absences from work. Obesity is associated with reduced participation in the workforce, increased absence from work, disability and health costs, lower salaries and reduced productivity.* **Objectives:** *We aimed at quantifying the limitations in range of motion (ROM) of the upper limb and the trunk of obese workers during basic occupational tasks.* **Methods:** *One group of 15 obese female subjects (BMI: 42.10±9.10 kg/m²) and one control group of 13 normal-weight female subjects were recruited. Three group of tasks were selected as representative of basic occupational movements: 1) upper limb movements (reaching, abduction-adduction, frontal elevation); 2) trunk movements (lateral bending, rotation); 3) whole body movement (target task).* **Results:** *We observed significant range of motion limitations in lateral and frontal upper arm elevation. Statistically significant difference in terms of center of pressure (the point of application of the ground reaction force measured by means of force platform) excursions was observed for lateral bending and trunk rotation tasks.* **Conclusions:** *Our results show that obese subjects have significant range of motion limitations of the upper body during basic occupational activities. This study provides quantitative evidence of these limitations of obese workers and may serve occupational specialists to allocate them to adequate jobs and reduce the rate of work-related musculoskeletal disorders.*

Riassunto

«Limitazioni della motilità articolare della parte superiore del corpo in lavoratrici obese». **Introduzione:** *Il numero di soggetti obesi è in aumento in tutto il mondo e le conseguenze economiche di un aumento della percentuale di lavoratori obesi sono rilevanti in termini di costi sanitari e assenze dal lavoro. Infatti, l'obesità è associata all'aumento delle assenze dal lavoro, disabilità e costi sanitari, salari più bassi e riduzione della produttività.* **Obiettivi:** *L'obiettivo di questo studio è la quantificazione delle limitazioni nella escursione articolare durante lo svolgimento di movimenti comuni svolti con il tronco e con gli arti superiori in un gruppo di lavoratrici obese.* **Metodi:** *Si sono reclutati un gruppo di 15 donne obese (BMI: 42.10±9.10 kg/m²) e un gruppo di controllo di 13 donne normopeso. Tre gruppi di attività sono stati scelti come rappresentativi delle tre attività lavorative fondamentali: 1) movimenti degli arti superiori (reaching, abduzione-adduzione, elevazione frontale); 2) movimenti del tronco (flessione laterale, rotazione); 3) movimento totale del corpo (raggiungimento di un target).* **Risultati:** *Si sono osservate limitazioni*

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articolari significative nell'elevazione laterale e frontale del braccio. Inoltre si è trovata una differenza statisticamente significativa in termini di escursione del centro di pressione (definito come il punto di applicazione del vettore forza corrispondente alla reazione vincolare del suolo e rappresenta una media pesata delle pressioni sulla superficie di contatto con il suolo) durante la flessione laterale e la rotazione del tronco. **Conclusioni:** *I risultati hanno mostrato che lavoratrici obese presentano significative limitazioni articolari della parte superiore del corpo durante lo svolgimento di attività occupazionali di base. I risultati di questo studio quantificano le limitazioni articolari della parte superiore del corpo di lavoratrici obese e possono aiutare il medico del lavoro ad allocare questi soggetti in mansioni congrue riducendo il rischio d'insorgenza di disturbi muscoloscheletrici.*

Introduction

The prevalence of obesity is increasing worldwide and the economic consequences of an increased percentage of obese workers are relevant in terms of health costs and absences from work. Obesity is associated with reduced participation in the workforce (21, 22), increased absence from work, disability and health costs (1, 9, 10, 23), lower education and salaries and reduced productivity (8, 14). It also causes a 13-fold greater loss of working days and an 11-fold higher number of compensation claims (5). Obese workers are typically involved in manual handling and are more often on sick leave for over 8 days at a time (3).

Excess weight imposes abnormal mechanics on body movements, which could account for the high incidence of musculoskeletal disorders in these subjects (12). Body shape is influenced by the excess of mass, which can limit the physiological range of motion at articular level, enhance the risk of musculoskeletal overload (25), reduce postural control (17) and gait ability (7). The latter affects a variety of daily and occupational tasks, particularly those performed with the upper limbs starting from a standing posture (2).

The speed of movements is generally lower in obese subjects, especially in anti-gravity actions (25). In the general population, the speed of hand movements slows down linearly with the decrease in the target dimension, but in obese subjects, this decay is significantly greater (2). Both the accuracy of fine movements and elbow range of movement, crucial for precise hand positioning, have been shown to lessen (2). Therefore, obese workers may be less precise and efficient in job tasks that call for precise upper limb movements while standing. Based on biomechanical data of the elbow, hand–wrist and dorsal spine, an overload of the gleno-humeral joint during job tasks can be hypothesised. Musculoskeletal disorders of the shoulder region are more frequent in obese subjects (18). The shoulder might indeed compensate the postural changes occurring at spinal level (dorsal stiffness) and the reduced range of motion at elbow and wrist level.

Obese workers have a four-fold higher probability of developing carpal tunnel syndrome as compared to normal-weight counterparts (19, 20, 26). Compared to the odd occupational risks (manual material handling, use of vibrating tools, adverse environmental conditions, physical strain, awkward posture, noise, duration of the work cycle), which are associated with a probability (odds ratio) of work-related musculoskeletal disorders between 1.8 and 5.2, obesity is associated with a 2.05 odds ratio; in particular, such risk is 48% higher in grade-3 obese subjects as compared to normal-weight subjects (11).

As for the spine, in obese subjects a limited flexibility and increased dorsal stiffness are evident (24), which affect the execution of job tasks involving the trunk.

Body mass has an impact on trunk kinematics during lifting, resulting in higher loads on the transverse and sagittal plane: during forward flexion of the trunk, the lumbar trait of the spine undergoes the highest torques and is therefore a major target of degenerative conditions (25).

Muscle strength also is affected by changes in body mass and composition: compared to their lean counterparts, obese subjects show both higher absolute fat and lean mass values; however, when normalized to body weight, strength appears 10% lower in obese subjects (4). Body mass, together with forearm and hand length, accounts for more than 85% of the variance of grip strength (13).

Despite such body of literature, the clinical evidence of the encumbrance of the additional fat masses and its impact on common job tasks, an objective quantification of the limitations in range of motion of the joints involved in job-related tasks is lacking. In this study, we aimed at quantifying with a 3D optoelectronic system the limitations in range of motion during basic occupational tasks involving the upper limb and the trunk in obese female workers.

Methods

Participants

One group of 15 obese female subjects (Obese Group: OG: age: 42±6 years; height: 1.61±0.07 m; weight: 108.00±21.00 kg, BMI: 42.10±9.10 kg/m^2; BMI range: 30.2-62.4 kg/m^2)referred to our outpatient facility for a weight management program and one control group of 13 normal-weight female subjects with no known pathologies (CG: age: 36±9 years; height: 1.64±0.05 m; weight: 58.00±8.00 kg, BMI: 21.40±2.80 kg/m^2) selected among the staff of our Institute, the Istituto Auxologico Italiano in Piancavallo, Italy, were recruited for this study. The obese participants were stratified in terms of BMI as follows: 3 participants with degree I of obesity (mean BMI=31.6 Kg/m^2), 5 participants with degree II of obesity (mean BMI=38.1 Kg/m^2) and 7 participants with degree III of obesity (mean BMI=50.8 Kg/m^2). All of the subjects in both groups were of working age. At the time of our study, they were all employed in sedentary or semi-sedentary jobs, involving no strenuous activities. Exclusion criteria for the obese and the control subjects were the presence of musculoskeletal, neurological, and/or cardiopulmonary conditions other than obesity that would hinder mobility capacity. All subjects were not involved in regular physical activities before entering the study, practising less than 1-2 hours/week of physical activity. None of them suffered from diabetes and hypertension, pain, headache, balance disorders and/or any other symptoms that could hamper the execution of the tests.

The study was in accordance with the Helsinki Declaration of 1975. Written informed consent was obtained from the participants.

Equipment

An optoelectronic system with passive markers (Vicon T40, Oxford Metrics Group, Oxford, UK), equipped with 6 cameras at a sampling rate of 100 Hz, to assess the kinematics, 2 force platforms (Kistler, Winterthur, CH), to evaluate kinetics, and a video system synchronized with the optoelectronic system and force platforms were used.

To evaluate the kinematics, passive markers were positioned on the participants' body, in particular on the upper limbs and trunk, according to a modified marker set described in literature (16).

Tasks description

Three group of tasks were selected as representative of basic occupational movements (figure 2):

1. Group 1 tasks: Upper limb movements (reaching, upper limb abduction-adduction, upper limb frontal elevation), representing basic components of common occupational tasks typical of supermarket checkers or employees sitting at the desk;
2. Group 2 tasks: Trunk movements (lateral bending, trunk rotation), also typical of supermarket checkers or employees sitting at the desk;
3. Group 3 task: Whole body movement (target task), representing basic components of common occupational tasks typical of store clerks, stockmen or employees dealing with some manual handling.

All participants were instructed to perform the 3 group of tasks at their preferred speed and to comfortably reach the maximum excursion without losing balance. Subjects were asked to perform 6 consecutive repetitions for each task. To minimize the fatigue effect, a 30 second rest interval between the tasks was allowed. The tasks were completed with both the right and the left arm, except for the target task that was performed using the dominant side. Two trials for each side were acquired for each task.

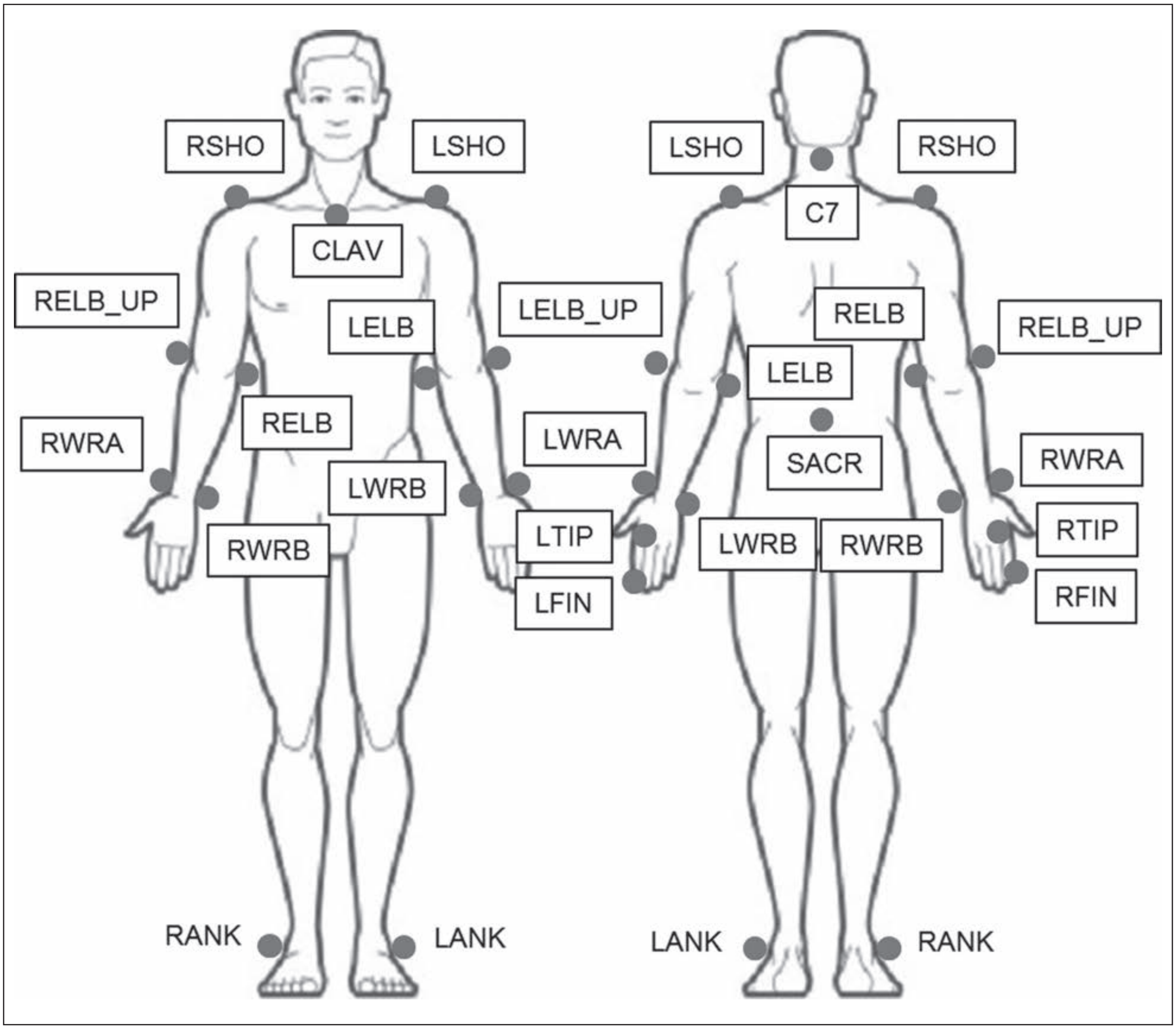

Figura 1 - Marker set used in the study

1. Group 1 tasks

Reaching (figure 2.1a): The subjects were comfortably seated on an adjustable stool (without arm- or back-rest) with a table positioned in front of them. The starting position for the task requires the subjects to place their hand on the table surface directly in front of them with the elbow flexed at 90°, the forearm in slight pronation and the wrist in a neutral position. Neither the trunk nor the head were restrained. The reaching task involves leaning forward and extending the elbow to touch a target positioned at normalized distance from the subject (target-acromion distance = 80% of arm length) in mid-line position.

Upper limb Lateral Elevation/Upper limb Frontal Elevation (figure 2.1b, 2.1c): same position as previous, with arms along their body and feet parallel without shoes. Subjects were asked to maintain their trunk and head in an upright position, to look straight ahead and to comfortably perform the maximal lateral/frontal elevation movements maintaining the elbow extended.

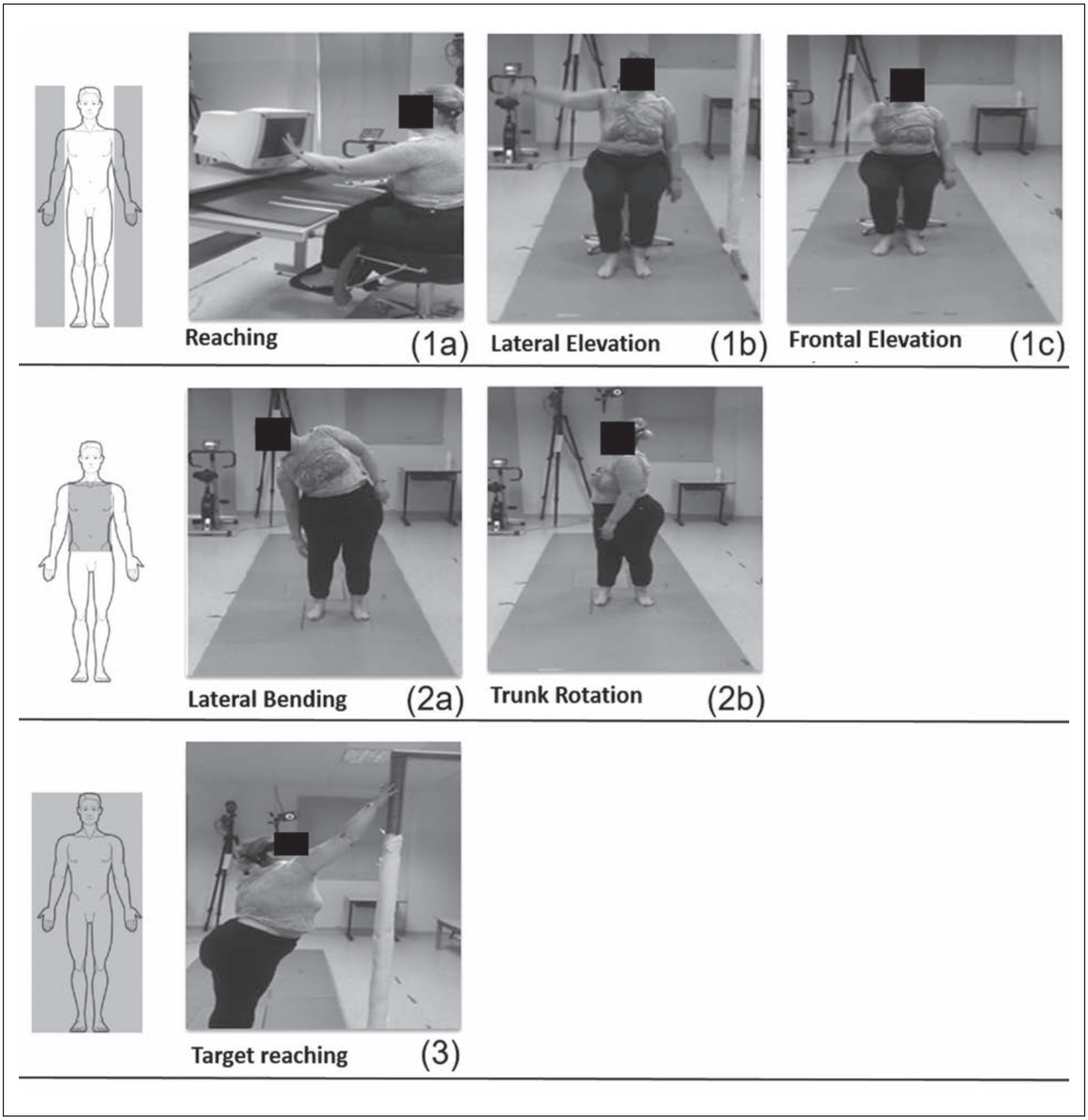

Figura 2 - The three group of tasks selected as representative of basic occupational movements.

2. Group 2 tasks

Lateral bending/Trunk rotation (figure 2.2a/2.2b): the subjects are in upright standing position, with both feet on a force platform; they were asked to maintain their trunk and head in upright position, to look straight ahead and to perform the maximal lateral bending/trunk rotation movements for 6 consecutive repetitions in a comfortable manner. The movements are requested before on the right/clockwise direction and then on the left/counter clockwise direction. Their arms were maintained along the body during lateral bending and rotation (15, 24).

3. Group 3 task

Target Task (figure 2.3): subjects were upright on a force platform with arms along the body in a neutral position and a vertical target positioned in front of them. The height of the target and the distance between the subject and the frame have been parameterized according to the anthropometric measures of the subject. In particular: the target height was defined equal to the distance between the floor and the finger in maximal vertical position; the distance between the subject and the frame, instead, was calculated as 80% of the length of subject's arm (acromion - index finger). In this way, the subject is asked to rise her heels in order to try reaching the target.

The task involved forward leaning and extending the dominant arm to touch the target.

Parameters description

From the data obtained by the optoelectronic system, the following parameters were computed using Smart Analyzer software (version 1.10.465.0 - BTS Bioengineering, Italy):

1. Group 1 tasks

Reaching (R): Each movement was segmented into three sequential phases as described elsewhere (6, 16): going phase (i.e. toward the target), adjusting phase (i.e. dedicated to precisely locating the target) and returning phase (i.e. toward the initial position).

The analysed parameters are as follows:

- Phases Duration (R-PD_G/_A/_R) (s): defined as the time required for completing the Going/Adjusting/Returning phase and Total Movement Duration (Total R-MD);
- Mean Movement Velocity (R-MMV) (m/s): it is computed during the task and it represents the mean velocity of the fingernail marker;
- Adjusting Sway (R-AS index) (mm): it is defined as the length of the 3D path described by the fingernail during the adjusting phase, which is a measure of the adjustments made to reach the final position and it represents an expression of the degree of precision;
- Range Of Motion at the shoulders (R-SROM) (degrees): calculated as the absolute difference between the maximum and minimum values of shoulder angles on the frontal plane (abdo/adduction movement), on the sagittal plane (flex/extension movement) and on the transversal plane (rotation movement) during the going phase (16);
- Range Of Motion at the elbows (R-EROM) (degrees): calculated as the absolute difference between the maximum and minimum values of elbow angles on the sagittal plane (flex/extension movement) during the going phase (16).

Upper limb lateral elevation (LE): Each movement was segmented into two sequential phases: elevation phase (i.e. defined as the phase between the start point and the maximum elevation) and descendent phase (i.e. defined as the phase between the maximum elevation and the end point - minimal elevation).

For the lateral elevation, the following parameters were defined:

- Arm angles (degrees): the maximum angle (LE-MAX), the minimum angle (LE-MIN) and the range of motion (LE-ROM), computed as the absolute difference between maximum and minimum value of the arm angle, calculated between a vector passing through the shoulder marker (bilaterally L/R SHO) and the middle point between the elbow markers (bilaterally L/R ELB and ELB_UP) and the vertical axes of the laboratory. This represents the arm movement on the frontal plane.
- Task Durations (s): defined as the time required for completing the elevation phase (LE-MD_UP), the descendent phase (LE-MD_DOWN) and the total movement duration for completing lateral elevation task (LE-MD).

Upper limb frontal elevation (FE): Similarly to the lateral elevation, each FE movement was segmented into two sequential phases: the elevation phase (i.e. defined as the phase between the start point and the maximum elevation) and descendent phase (i.e. defined as the phase between the maximum elevation and the end point - minimal elevation)

For the frontal elevation, the following parameters were defined:

- Arm angle (degrees): the maximum angle (FE-MAX), the minimum angle (FE-MIN) and the range of motion (FE-ROM), computed as the absolute difference between maximum and minimum value of the arm angle, calculated between a vector passing through the shoulder marker (bilaterally L/R SHO) and the middle point between the elbow markers (bilaterally L/R ELB and ELB_UP) and the vertical axes of the laboratory. This represents the arm excursion on the sagittal plane.
- Task Durations (s): defined as the time required for completing the elevation phase (FE-MD_UP), the descendent phase (FE-MD_DOWN) and the total movement duration for completing frontal elevation task (FE-MD).

2. Group 2 tasks

Lateral bending (LB): Each movement was divided into a going phase (i.e. defined as the phase between the start position and the maximum bending position) and a returning phase (i.e. defined as the phase between the maximum bending position and the consecutive start position).

For the lateral bending, the following parameters were defined:

- Trunk angle (degrees): the maximum angle (LB-MAX), the minimum angle (LB-MIN) and the range of motion (LB-ROM), computed as the absolute difference between maximum and minimum value of the trunk angle, calculated between the shoulder vector (defined as the vector between the left shoulder marker and the right shoulder marker - LSHO and RSHO) and the horizontal axes of the laboratory (on the frontal plane).
- Task Durations (s): defined as the time required for completing the going phase (LB-MD_G), the returning phase (LB-MD_R) and the total movement duration for completing lateral bending task (LB-MD).

In addition, during this task, the Centre of Pressure (CoP) acquisition was analysed through the force platform. The CoP is defined as the point of application of the ground reaction force vector representing the sum of all forces acting between a physical object and its supporting surface. In particular, it refers to the point at which the pressure of the body over the soles of the feet would be if it were concentrated in one spot. In particular, the following parameters related to the CoP were investigated:

- CoP excursion: the maximum CoP excursion during the lateral bending along the medio-lateral direction (LB-CoP_ML), along the ante-posterior direction (LB-CoP_AP) (mm).
- CoP length (LB-CoP_L) (mm): the CoP trajectory length during the movement.

All CoP parameters were normalized to the participant's height (expressed in meters).

Trunk rotation (TR): Also for the trunk rotation (TR) task, each movement was divided into a going phase (i.e. defined as the phase between the start position and the maximum rotation position) and a returning phase (i.e. defined as the phase between the maximum rotation position and the consecutive start position).

For the trunk rotation, the following parameters were defined:

- Trunk angles (degrees): the maximum angle (TR-MAX), the minimum angle (TR-MIN) and the range of motion (TR-ROM), computed as the absolute difference between maximum and minimum value of the trunk angle, calculated between the shoulder vector (defined as the vector between the left shoulder marker and the right shoulder marker - LSHO and RSHO) and the horizontal axes of the laboratory (on the transversal plane).
- Task Durations (s): defined as the time required for completing the going phase (TR-MD_G), the returning phase (TR-MD_R) and the total movement duration for completing the trunk rotation task (TR-MD).

In addition, during this task, the Centre of Pressure (CoP) acquisition was analysed through the force platform. In particular, the following parameters related to the CoP were investigated:

- CoP excursion: the maximum CoP excursion during the lateral bending along the medio-lateral direction (TR-CoP_ML), along the an-

tero-posterior direction (TR-CoP_AP) (mm).
- CoP length (TR-CoP_L) (mm): the CoP trajectory length during the movement.

All CoP parameters were normalized to the participant's height (expressed in meters).

3. Group 3 task

Target Task: Each movement was segmented into two sequential phases: going up phase (i.e. toward the target) and returning down phase (i.e. back to the initial position).

For the target task, the following parameters were defined:
- Arm angle (degrees): the maximum angle (TARG-MAX), the minimum angle (TARG-MIN) and the range of motion (TARG-ROM), computed as the absolute difference between maximum and minimum value of the arm angle, calculated between a vector passing through the arm and the vertical axes of the laboratory. This represents the arm movement on the sagittal plane.
- Trunk angle (degrees): the maximum angle (TARG-TKMAX), the minimum angle (TARG-TKMIN) and the range of motion (TARG-TKROM), computed as the absolute difference between maximum and minimum value of the shoulder angle, calculated between a vector passing through C7 and SACR markers and the vertical axes of the laboratory. It represents the trunk movement on the sagittal plane.
- Task Durations (s): defined as the time required for completing the going phase (TARG-MD_G), the returning phase (TARG-MD_R) and the total movement duration for completing frontal elevation task (TARG-MD).
- Heel elevation (mm): from the vertical coordinates of the ankle marker, the vertical elevation was defined (maximum elevation during the going phase) (TARG-ELEV).

In addition, during this task, the Centre of Pressure (CoP) acquisition was performed through the force platform. In particular, the following parameters related to the CoP were investigated:
- CoP excursion during the lateral bending along the medio-lateral direction (TARG-CoP_ML), along the antero-posterior direction (TARG-CoP_AP) (mm).
- CoP length (TARG-CoP_L) (mm): the CoP trajectory length during the movement.

All CoP parameters were normalized to the participant's height (expressed in meters).

Statistics

All parameters were computed bilaterally for each participant and the median and quartile range values of all indexes were calculated for each group (OG and CG). Kolmogorov–Smirnov tests were used to verify if the parameters were normally distributed; the parameters were not normally distributed, so we used the Mann Whitney U-test for comparing data between two groups. Level of significance was set at $p<0.05$.

Results

Age and height were not significantly different among groups, while BMI and weight differed significantly between OG and CG. All participants were able to perform the required tasks.

1. Group 1 tasks

Reaching: Results showed significantly higher values of the adjusting sway parameter (R-AS), indicative of movement precision, and higher ROM values on frontal plane in OG than in CG (table 1).

Table 1 - Median (quartile range) values of the parameter measured during reaching in OG and CG

	OG	CG
R-PD_G [s]	0.67 (0.21)	0.62 (0.12)
R-PD_A [s]	0.20 (0.09)	0.18 (0.08)
R-PD_R [s]	0.68 (0.21)	0.66 (0.13)
R-MMV [m/s]	0.65 (0.23)	0.69 (0.13)
R-AS index [mm]	18.3 (15.7)*	13.95 (10.2)
R-SROM Abd/Add [°]	16.0 (10.37)*	10.60 (8.55)
R-SROM Flex/Ext [°]	57.6 (15.4)	55.35 (8.57)
R-SROM Rotation [°]	33.6 (17.77)	33.00 (11.50)
R-EROM Flex/Ext [°]	34.7 (20.47)	30.00 (15.30)

*=$p<0.05$

Upper Limb Lateral Elevation: All the angular parameters were statistically significant between OG and CG. In particular, the arm's ROM (LE-ROM) and the maximum arm angle (LE-MAX) were lower in OG as in CG and an increased minimum angle (LE-MIN) was observed in OG. No differences in duration parameters were detected during this task (table 2).

Upper Limb Frontal Elevation: Similarly to LE, angular parameters were statistical different between the two groups. OG have a lower ROM (FE-ROM) due to a reduced maximum elevation angle (FE-MAX). The minimum angle (FE-MIN) in OG showed higher values as compared to CG. In terms of velocity, OG performed the task slower than CG (with longer duration of the task FE-MD). Similar results were found during the going up and returning down phases (FE-MD_UP and FE-MD_DOWN) (table 3).

2. Group 2 tasks

Lateral bending: OG and CG did not show significant differences during this task, with the exception of the duration of the returning down phase (LB-MD_R), where OG were slower than CG. In terms of CoP parameters, OG showed a higher excursion at anterior-posterior direction (LB-COP_AP) and a lower medial-lateral excursion value (LB-COP_ML) (table 4).

Trunk rotation: No differences were evident in terms of angular and temporal parameters. In terms of CoP parameters, OG presented higher length values (TR-CoP_L) as compared to CG and higher CoP excursions in the anterior-posterior direction (TR-CoP_AP) (table 5).

3. Group 3 task

Target Task: A significant difference in terms of trunk angles was evident, but not so for the arm angles. While the maximum, minimum angles and

Table 2 - Median (quartile range) values of the parameter measured during upper limb lateral elevation in OG and CG

	OG	CG
LE-MAX [°]	152.72 (17.21)*	157.40 (8.81)
LE-MIN [°]	22.56 (5.4)*	13.05 (6.441)
LE-ROM [°]	134.12 (18.46)*	144.69 (8.12)
LE-MD [s]	9.60 (4.23)	9.41 (6.17)
LE-MD_UP [s]	0.79 (0.42)	0.77 (0.56)
LE-MD_DOWN [s]	1.02 (0.45)	0.93 (0.55)

*=p<0.05

Table 3 - Median (quartile range) values of the parameter measured during upper limb frontal elevation in OG and CG

	OG	CG
FE-MAX [°]	155.98 (13.35)*	161.27 (10.32)
FE-MIN [°]	12.2 (15.22)*	9.12 (4.96)
FE-ROM [°]	142.86 (20.26)*	152.18 (9.35)
FE-MD [s]	9.69 (3.93)*	8.07 (3.77)
FE-MD_UP [s]	0.88 (0.34)*	0.70 (0.31)
FE-MD_DOWN [s]	0.98 (0.29)*	0.81 (0.37)

*=p<0.05

Table 4 - Median (quartile range) values of the parameter measured during lateral bending in OG and CG

	OG	CG
LB-MAX [°]	43.04 (6.89)	44.87 (10.05)
LB-MIN [°]	3.19 (2.30)	3.23 (3.05)
LB-ROM [°]	38.61 (9.11)	40.54 (10.7)
LB-MD [s]	10.52 (3.77)	9.22 (4.56)
LB-MD_R [s]	0.63 (0.21)	0.60 (0.38)
LB-MD_G [s]	1.24 (0.33)*	1.09 (0.39)
LB-COP_AP [mm/m]	0.11 (0.04)*	0.08 (0.06)
LB-COP_ML [mm/m]	0.27 (0.15)*	0.31 (0.11)
LB-COP_L [mm/m]	3.21 (1.00)	3.34 (1.41)

*=p<0.05

Table 5 - Median (quartile range) values of the parameter measured during trunk rotation in OG and CG

	OG	CG
TR-MAX [°]	91.72 (29.05)	86.68 (23.37)
TR-MIN [°]	2.48 (1.45)	2.62 (1.78)
TR-ROM [°]	86.90 (32.91)	83.04 (23.20)
TR-MD [s]	10.79 (2.65)	10.41 (4.22)
TR-MD_G [s]	0.75 (0.26)	0.69 (0.32)
TR-MD_R [s]	0.80 (0.29)	0.74 (0.38)
TR-COP_AP [mm/m]	0.13 (0.04)*	0.09 (0.07)
TR-COP_ML[mm/m]	0.12 (0.06)	0.12 (0.08)
TR-COP_L [mm/m]	2.03 (0.53)*	1.72 (1.01)

*=p<0.05

Table 6 - Median (quartile range) values of the parameter measured during the target task in OG and CG

	OG	CG
TARG-MAX [°]	105.26 (13.01)	107.28 (15.11)
TARG-MIN [°]	28.67 (10.36)	24.60 (14.59)
TARG-ROM [°]	77.03 (21.92)	76.02 (28.67)
TARG-TKMAX [°]	7.48 (2.56)*	5.72 (3.68)
TARG-TKMIN [°]	0.03 (0.03)*	0.02 (0.49)
TARG-TROM [°]	7.42 (2.85)*	5.24 (3.52)
TARG-MD [s]	11.50 (1.78)	10.13 (3.03)
TARG-MD_G [s]	0.88 (0.23)	0.79 (0.27)
TARG-MD_R [s]	1.24 (0.21)	1.11 (0.33)
TARG-ELEV [mm]	120.01 (22.22)*	140.25 (12.49)
TARG-COP_AP [mm/m]	0.18 (0.13)	0.17 (0.09)
TARG-COP_ML[mm/m]	0.47 (0.09)*	0.51 (0.09)*
TARG-COP_L [mm/m]	6.15 (1.22)	6.47 (1.99)

*=$p<0.05$

trunk ROM (TARG-TRMAX. TARG-TKMIN and TARG-TKROM) were significant higher in OG than CG; no statistical differences were shown in terms of arm angle parameters. AS for CoP, significant differences were found in the medial-lateral direction (TARG-CoP_ML), with lower values in OG. Foot elevation (TARG-ELEV) was statistical different between two groups; this parameter was lower in OG as in CG (table 6).

Discussion

The aim of this study was to quantify with a gold-standard 3D method the restrictions in upper body movements of obese subjects during common tasks representing basic components of occupational tasks. In addition to the known risk factors (age, female gender, repetitive work, strain and demanding exertions, localized pressure, posture, environmental temperature, exposure to vibration, job design), obesity *per se* represents a risk factor for the onset of work-related musculoskeletal disorders. Despite the high prevalence of work-related musculoskeletal disorders in obese workers, the obesity-related risk of work-related injuries linked to common job tasks has been poorly investigated so far.

Our results add information to clinical observation providing quantitative evidence that obese subjects present limitations in upper arm and upper body basic movements that ultimately reduce their work capacity.

In particular, we have observed significantly reduced movement precision of the upper arm in a reaching task and limitations in lateral and frontal upper arm elevation ROM. Such findings can be attributed to the encumbrance of limb volumes and fat distribution that obese subjects present at proximal arm and trunk level, influencing the precision and the degrees of freedom of the upper limb.

As for trunk lateral bending, it appears that obese workers reduce the center of pressure lateral movement in order to maintain stability. Such findings are in line with previous experimental observations (17) documenting poorer balance control in obese subjects as compared to their lean counterparts.

The main limitation of our study is the small size of the experimental sample that prevents an evaluation by BMI categories. Future studies on larger samples should be conducted, so as to perform a stratification according to the degree of obesity and to evaluate differences in terms of quantitative biomechanical parameter among BMI groups.

Despite such limitations, our results document a reduced work capacity of obese workers during specific basic movements representative of common occupational tasks performed by employees such as clerks, checkers and stockmen. Such quantitative findings may be useful for occupational physicians, employers and ergonomists when considering the suitability to specific job tasks for obese workers. Bearing in mind range of motion limitations and decreased precision in tasks performed with the upper limbs may help allocating them to jobs whose demands are matched with work capacity, and, ultimately, reducing the rate of work-related musculoskeletal disorders. Future recommendations for managing job restrictions or ergonomic changes to the workplace for the obese workforce may consider these findings. In the wake of these findings, we also propose that recommended weight limits and dimensional parameters (horizontal and vertical distance) for manual handling, which have been set for normal-weight workers, should be recalculated for the obese workforce.

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