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Global Upper Body Assessment (GUBA) - A new Tool to Identify the Indicators That will lead to the Occurrence of Musculoskeletal Disorders of Light Weight Loads in Seated Position Based Body Mass Index and Postural Strategy

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ABSTRACT

Musculoskeletal disorders (MSDs) are increasingly prevalent in industrialized countries, and have a major financial impact. Their prevention requires new ergonomic tools to better understand and assess the risks. The objective was to propose the Global Upper Body Assessment (GUBA) tool for investigating indicators that will lead to the occurrence of MSDs in the workplace, in daily life or at home. GUBA was applied to interaction tasks with handheld digital devices weighing from 0 to 1 kg in a sitting position, with or without support for the upper limbs. The GUBA tool was developed in three stages: 1) modeling to quantify joint parameters, joint torques and reaction forces from subject's BMI, mass handled, and postural strategy; 2) development of risk scales; 3) computation of the GUBA score. A set of abacuses has been created to enable the user to directly read the GUBA score and the corresponding MSD risk level. The abacuses are very easy to use: simply select the abacus for the situation (sitting with or without support), choose the table corresponding to the mass handled, identify the user's BMI, choose the postural strategy, and finally read the GUBA score at the end of the line.

Keywords: Musculoskeletal disorders; ergonomic assessment; posture; joint load; support; smartphone; handheld digital devices.

INTRODUCTION

For several years now, musculoskeletal disorders (MSDs) have been on the rise, both in the workplace and in industry, and increasingly in leisure activities [1]. The areas most affected are the cervical spine, lumbar spine and upper limbs. In 2017, these disorders accounted for 87% of recognized occupational illnesses in France, making them the leading cause of work stoppages. Compensated MSDs resulted in the loss of approximately 10 million working days and 1 billion euros in costs covered by contributions [2].

With the rise of new technologies, particularly touch-screen devices, numerous studies have reported the emergence of MSDs linked to the frequency of use and the postures adopted during interaction [3,4]. Several tools have been developed to study, from an ergonomic point of view, the conditions under which a task is performed.

Takala et al. (2010) [5] have compiled an exhaustive list of MSD assessment tools that qualify a potential risk for the appearance of MSDs and provide information on the urgency of modifying high-risk situations in order to protect the health of users. The methods used can be divided into three categories: subjective assessments based mainly on the use of questionnaires (for example the Quick Exposure Check – QEC [6], Hand Activity level and Threshold Limit Value – HAL-TLV [7], an Assessment tool for Repetitive Tasks of the upper limbs – ART [8], or the Risk Assessment and Management tool for manual handling Proactively – RAMP [9]), systematic observations and direct measurements [10], and observational assessments. In this latter, the best known are the Occupational Repetitive Actions – OCRA [11,12], the Rapid Upper Limb Assessment – RULA [13], the Rapid Entire Body Assessment – REBA [14], or the Hand Arm Risk Assessment Method – HARM [15]. They are simple, inexpensive, easy to implement and often more flexible than other methods. All these assessment tools are based mainly on posture, and include other task-related information (presence of vibrations, mass carried, etc.) to define the level of risk, but with varying degrees of precision. Studies have been conducting to compare the results obtained with these different tools [16]. For example, a recent study conducted by Yazdanirad et al. [17] showed that RULA appeared to be a robust method for assessing the MSDs risk compared to LUBA (Loading on the Upper Body Assessment, [18]) and NERPA (New Ergonomic Posture Assessment, [19]). In these tools, the evaluation of posture does not take into account the anthropometric characteristics of the subjects. Yet we know that parameters such as height or mass induce changes in muscle loads [20] particularly in the spine [21,22], discomfort and pain [23] or MSD prevalence [24]. Task-related parameters are generally considered macroscopically. Among the most widely used, the presence of a support, known to be beneficial for MSD prevention [25,26], is characterized by a localized weighting index. The forces exerted on these supports are not taken into account, even though they can be a source of discomfort and pain, and lead to pathologies [27]. Finally, joint constraints (i.e. joint torques) generated by the manipulation of an object are characterized by a coefficient directly related to its mass. However, we know that joint torques and muscular forces are also linked to posture [28]. It would be interesting not to manipulate coefficients but biomechanical parameters (support reaction forces and joint torques) for a more accurate ergonomic assessment of MSDs.

The objective of this paper was to present a global approach to upper body risk assessment called the Global Upper Limb Assessment (GUBA). This new tool was applied to the smartphone use which represents an interesting research framework for MSD prevention. Indeed, it is a very frequent and repetitive activity throughout the day, with a total duration of approximately 3.7 hours per day [29,30]. Thus, many works have studied the interaction between a smartphone and its user during different conditions of use (sitting [31], standing [32], walking [33]) and different tasks (texting [31], web browsing [33] or watching video [26]). The present study focused on the sitting position, position widely observed in students [34] or maintained for several hours at work [35]. This is observed at work, at home, for leisure activities or in transport with or without support when interacting with a lightweight (0-1 kg) digital device. The work of Merbah et al. (2020) describes the behaviour of a user when texting and web browsing while sitting in a chair in front of a table with a support for elbows or forearms, or in the absence of this support [36]. Based on a hierarchical cluster analysis, the results showed three postural strategies for performing the same task: the “neck strategy” (which mainly involves the neck), the “trunk strategy” (the subjects mainly bend the trunk), and the “mixed strategy” (which combines the two previous strategies). By considering the trunk and neck flexions and the distance between the head and the smartphone, the authors highlighted four different postural clusters for each of the two tasks. These eight strategies had different values of head and neck flexion and head-to-smartphone distance and reflect the inter-individual variability that exists when performing the same task. The GUBA relies on the existence of these postural strategies to develop a score that integrates joint angles, joint torque and support reaction forces based on experimental measurements of these two situations.

MATERIALS & METHODS

The GUBA score computation has been generalized to all seated situations, with support (ST) or without support (SWT), when interacting with a digital device with a mass less than or equal to 1 kg (smartphones, handheld game consoles, tablets, etc.). The assessment tool was developed in three stages: 1) modeling to quantify joint parameters, joint torques and reaction forces; 2) development of risk scales; 3) calculation of the GUBA score. Following these steps, a set of abacuses was created to enable the user to read this score for a given BMI, postural strategy and manipulated mass (between 0 and 1kg).

Step 1: Modelisation

The first stage of the work consisted of developing a geometric model of an individual from experimental data obtained for each of the eight postural strategies observed among smartphone users proposed by Merbah et al. [36]. Based on these previous results, the interaction task took place mainly in the sagittal plane. Then, the model only took into account the movements performed in this plane. Six segments have been considered: five body segments, i.e. the trunk, head, arm, forearm, hand and the largest dimension of a smartphone. De Leva's anthropometric tables were implemented in the model to compute the length and mass of each of the five body segments from the height of the subject and total mass [37]. The length of the smartphone was modelled on the basis of the average dimensions of the devices used by the subjects in Merbah et al. study [38]. The average length was estimated at 138 mm.

Nine inputs were used to set up the model. First, trunk, neck, elbow and shoulder flexion and radio-ulnar deviation of the wrist were used as postural variables. Secondly, the distance between the face and the smartphone, the weight of the device and the orientation of the screen represent the variables related to the device. Finally, to generalize the use of the GUBA, a range of 12 different morphologies were considered. They were chosen on the basis of body mass index (BMI), i.e. by considering the size and mass of individuals, in order to best represent the different morphotypes present in a population. Table 1 presents the 12 selected morphologies, with BMIs ranging from 12.5 to 50, which were also considered as input data for the model.

Table 1. Anthropometric characteristics of the 12 morphologies used as input data for the model.

BMI	Height (m)	Weight (kg)	BMI	Height (m)	Weight (kg)
12.5	2.00	50	30.0	1.55	72
18.3	1.55	44	34.6	1.55	83
18.8	2.00	75	34.6	1.90	125
25.4	1.60	65	39.5	1.55	95
25.0	2.00	100	39.5	1.80	128
29.8	2.00	119	50.0	1.55	120

Based on these data and on the fundamental principle of statics, three groups of variables were considered to define the interaction task with a smartphone in a seated position, with or without support. The first category of parameters includes joint torques measured at the trunk, neck, shoulder, elbow and wrist. They have been chosen because they represent the muscular activity necessary to maintain posture during the task achievement [39]. The support reaction forces constitute the second category. They are important information for the stability of the posture and can be a source of discomfort and pain when the loads or the duration become too high. The last category is defined by all the angular variables of the trunk, neck and upper limb that define the posture in sagittal plane. These postural factors are acknowledged in the literature to play a major role in the risk of MSDs. [13,18,19]. The following figure (Figure 1) shows the structure of the model for each positon:

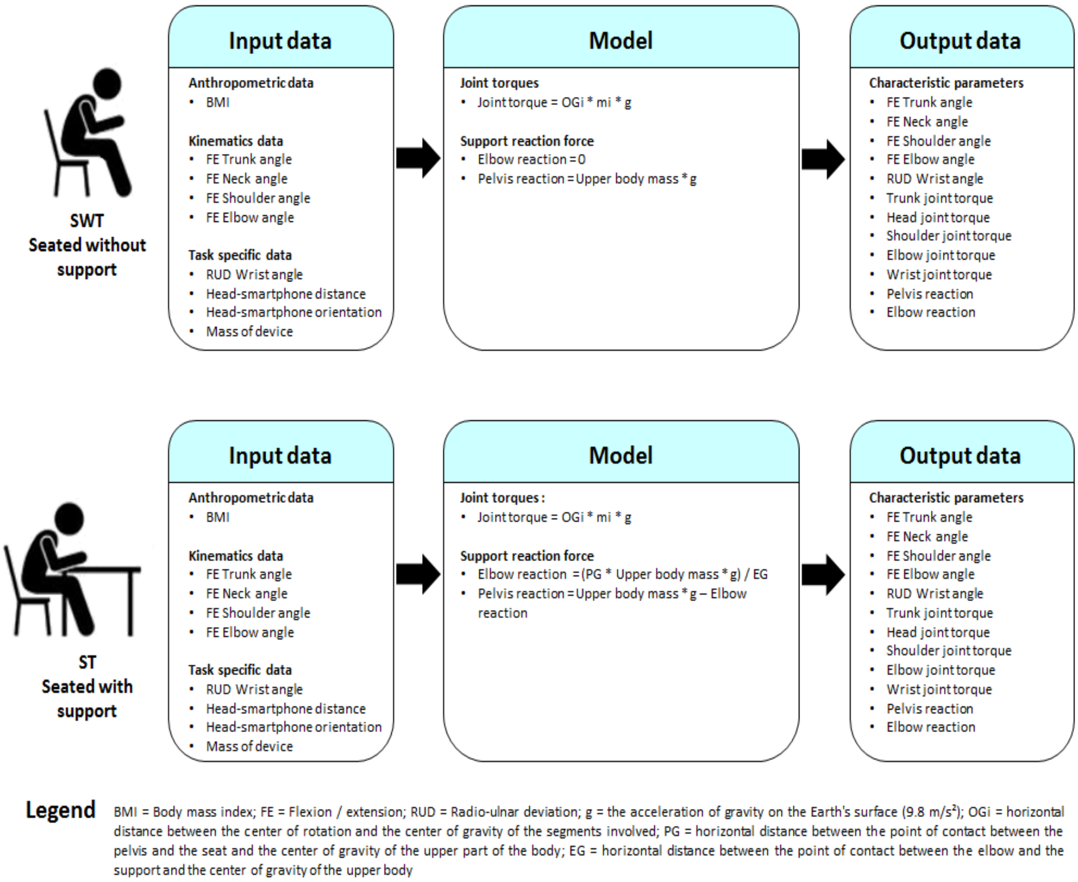


Figure 1. Model used to build the GUBA score.

The model's output data are used to produce two abacuses (seated situation without support and with support) providing the values of twelve characteristic parameters (5 joint angles, 5 joint torques and 2 reaction forces) for each of the eight strategies and each of the twelve selected BMIs. These two abacuses (table 12x96) correspond respectively to part A (left panel) of figures 2 and 3. Joint torques and support reaction forces were computed for lightweight objects, i.e. between 0 and 1kg, with an increment of 50g, i.e. a total of 21 tables per situation. The data presented in the two tables in Figure 2 and Figure 3 (Panel A) correspond values computed for the maximum light load (1 kg).

Step 2: MSD risk scale construction

This stage consisted in the constriction of scales linking the values of the twelve parameters derived from the model to MSD risk levels. These risk scales range from 0 to 2 based on the principle of work presented in the literature: a score of 0 indicates a low risk of developing MSDs (green colour), a score of 1 indicates a medium level of risk (yellow colour), and a score of 2 indicates a high level of risk (red colour). The relation between the range of motion of the axial skeleton and upper limbs and the corresponding scores has been developed on the basis of the principle proposed by other ergonomic tools such as RULA [13], LUBA [18], REBA [14]. For neck, trunk, and shoulder flexion, the three risk levels with their respective thresholds correspond to those presented in RULA and REBA (with the exception of the 4th risk level for the shoulder, which has been included in the 3rd). For the elbow, the two RULA REBA levels have been retained (no third risk zone). Finally, for the wrist, smartphone orientation is mainly based on radio-ulnar deviation. LUBA data were therefore chosen to define GUBA thresholds for this region (RULA and REBA consider radio-ulnar deviation only through a weighting coefficient).

Based on the same principle, a risk scale has been proposed for neck, trunk, and upper limb joint torques. The scale limits were defined using data available in the literature. Ripamonti et al. [40] and Kauther et al. [41] reported maximum extensor torques de 4.6 Nm.kg-1 and 6.62 Nm.kg-1 respectively for lumbar and cervical spine. These joint torques respectively correspond to 368 Nm and 530 Nm for a man with an average weight of 80 kg. Koski and McGill [42] found a shoulder flexion torque of 89.9 Nm for a male in static position. Guenzkofer, et al. [43] reported an elbow flexion torque of 60 Nm in a 90° flexed position. For the wrist, Xia et al. [44] measured during maximal isometric contraction a radial and ulnar joint torque about 13 Nm. A physiologic consensus was found about the fact that 50% of the maximum force is considered as a light load that can be repeated many times or maintained for a long time [45]. Therefore, it can be assumed that this muscular load does not present any MSD risk. However, this limit is purely physiological in the field of sport. When handling handheld devices, the activity is almost static. It is therefore advisable to set the threshold significantly below 50%, as static postures induce greater fatigue than dynamic activities. [46]. In the field of work ergonomics, threshold values significantly lower than 50% have been proposed. Monod (1956) [47] and Rohmert (1960) [48] reported that a contraction of 15-20% of MVC could be maintained over a long period, as it did not disturb muscle homeostasis. During sustained static contraction, Jørgensen et al. (1988) [49] reported an endurance time of one hour at 10% MVC. They also found a 12% loss of max MVC after one hour of contraction at 5% MVC. Bjørksten and Jonsson (1977) [50] identified an average endurance time of 7.9% MVC for the same duration. When static contraction is intermittent, Bjørksten et al. measured an average contraction force of 14% over one hour. An similar value over a working day (7h) was found by Jørgensen et al. (1988) [49], but associated with a reduction in the spectral frequency of several muscle groups. This reduction was not observed with 10% MVC. The present study is not proposed in the context of work, i.e. with constrained, repetitive tasks, in an often fixed environment. Interaction with a smartphone or handheld device is an everyday task that the user can perform wherever, whenever and however he or she wishes, without postural or environmental constraints. As a result, this task can be likened to a long-duration intermittent static activity. Moreover, the mass of handheld portable devices is less than 1kg. For these reasons, we have chosen an intermediate value of 10% as the first threshold of the GUBA risk scales [49]. Below this threshold, the MSD risk was defined as low (score equal to 1, green colour).

Two studies performed by Na et al. [51] and Kee and Lee [52] reported discomfort score of 6 using a Borg CR10 scale, i.e. strong discomfort, for a 90° shoulder flexion and a 45° elbow flexion when a 3 kg load was handled. Due to the fact that discomfort is strongly related to the MSDs [53], it can be assumed that the risk of developing MSDs is greater beyond this value. For male with an average weight of 80 kg, this corresponds to 49 Nm and 17 Nm for the shoulder and elbow respectively. These values were set as the second scale limits between a moderate (rated at 2) and a high MSD risk (rated at 3). No data on the intermediate zone of discomfort or pain could be used to define the second threshold (medium to high risk) for the neck, trunk and wrist.

Regarding reaction forces, studies on soft tissue compressions have reported that for a pressure less than 4.3 kPa the capillaries would not be obstructed and therefore in ischemia [54,55]. Above a constant pressure of 9.3 kPa, soft tissue compressions produced irreversible cellular changes potentially associated with pain [55,56]. Assuming an average seating surface of 0.07 m² [57], the corresponding reactions forces to the pelvis were 300 N and 660 N respectively. Finally, no data were found for the support reaction forces for the elbow. Then, a protocol was carried out on 5 subjects with BMIs between 19 and 35. The subjects were asked to hold a 1kg load for 15 seconds for 5 different trunk flexions: 0, 10, 20, 30, and 40°. The elbow flexion angle was set at 90°. Reaction force at the elbow was measured using a force platform (Kistler, Switzerland). Elbow discomfort was assessed using a Rating Perceived Discomfort (RPD) with a Borg CR10 Scale. All subjects reported a RPD >=3 from 10° of trunk flexion. We therefore considered as threshold the reaction force of the subject with the highest BMI (35) in the 0° trunk flexion configuration, i.e. 50N.

Table 2. GUBA risk scales

		Low risk	Medium risk	High risk
Joint angles	Neck flexion	0–10°	10–20°	>20°
	Trunk flexion	0–20°	20–60°	>60°
	Shoulder flexion	-20–20°	20–45°	>45°
	Elbow flexion	60–100°	0–60° and >100°	-
	Wrist radio-ulna deviation	-10–10°	-10–(-20)° and 10–30°	<-20° and >30°
Joint torques	Neck extensor muscles	0–53 Nm	-	-
	Trunk extensor muscles	0–37 Nm	-	-
	Shoulder flexor muscles	0–9 Nm	9–49 Nm	>49 Nm
	Elbow flexor muscles	0–6 Nm	6–17 Nm	>17 Nm
	Wrist – radial deviation muscles	0–1.3 Nm	-	-
Support Reaction forces	Pelvis	0–300 N	300–660 N	>660 N
	Elbow	0–50 N	-	-

Step 3: Computation of the GUBA score

By applying the risk scales (Figures 2 and 3, panel B) to the abacuses for the two situations (tables 12x96, Figures 2 and 3, panel A), we obtain the MSD risk abacuses for the 12 model parameters over all 96 conditions. An example is shown in figures 2 and 3, panel C, for a mass of 1kg.

The GUBA score is then computed from these 12 MSD scores for each condition, using the following heuristic:

$$GUBA = \sum_{i=1}^{12} \alpha_i P_i$$

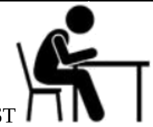
with: α_i correspond to the heuristic coefficient defined in table 2 and P_i correspond to the MSD scores. For the smartphone application, we have the following relationship:

$$GUBA = \alpha_1\theta_{Trunk} + \alpha_2\theta_{Neck} + \alpha_3\theta_{Shoulder} + \alpha_4\theta_{Elbow} + \alpha_5\theta_{Wrist} + \alpha_6 C_{Pelvis} + \alpha_7 C_{Neck} + \alpha_8 C_{Shoulder} + \alpha_9 C_{Elbow} + \alpha_{10} C_{Wrist} + \alpha_{11} R_{Pelvis} + \alpha_{12} R_{Elbow}$$

with: θ_{Trunk}, θ_{Neck}, $\theta_{Shoulder}$, θ_{Elbow}, and θ_{Wrist} which respectively represent the MSD scores associated with trunk, neck, shoulder, and elbow flexion, and wrist radioulnar deviation (figures 2 et 3 panel C, column 1 to 5); C_{Pelvis}, C_{Neck}, $C_{Shoulder}$, C_{Elbow}, and C_{Wrist} represent the MSD scores of joint torque respectively calculated at pelvis, the neck, the shoulder, the elbow and the wrist level (figures 2 et 3 panel C, column 6 to 10); R_{Pelvis} et R_{Elbow} represent the MSD scores of the support reaction forces of the chair on the pelvis and the support on the elbow or forearm (seated situation with support, figures 2 et 3 panel C, column 11 to 12).

Table 2 presents the values of the weighting coefficients α_i for each of the two interaction situations to be applied to each of the criteria used to calculate the GUBA score.

Table 2. Criteria definition to compute the GUBA score.

 ST		 SWT		
α_i Values		α_i Values		Description
α_1	1	α_1	1	Coefficient for trunk flexion θ_{Trunk}
α_2	1	α_2	1	Coefficient for neck flexion θ_{Neck}
α_3	1	α_3	1	Coefficient for shoulder flexion $\theta_{Shoulder}$
α_4	1	α_4	1	Coefficient for elbow flexion θ_{Elbow}
α_5	1	α_5	1	Coefficient for wrist radio-ulnar deviation θ_{Wrist}
α_6	1	α_6	1	Coefficient assigned to the torque measured at pelvis C_{Pelvis}
α_7	1	α_7	1	Coefficient assigned to the torque measured at neck C_{Neck}
α_8	0	α_8	1	Coefficient assigned to the torque measured at shoulder $C_{Shoulder}$
α_9	1	α_9	1	Coefficient assigned to the torque measured at elbow C_{Elbow}
α_{10}	1	α_{10}	1	Coefficient assigned to the torque measured at wrist C_{Wrist}
α_{11}	1	α_{11}	1	Coefficient assigned to the reaction force of the seat on the pelvis R_{Pelvis}
α_{12}	1	α_{12}	0	Coefficient assigned to the reaction force of the table on the elbow R_{Elbow}

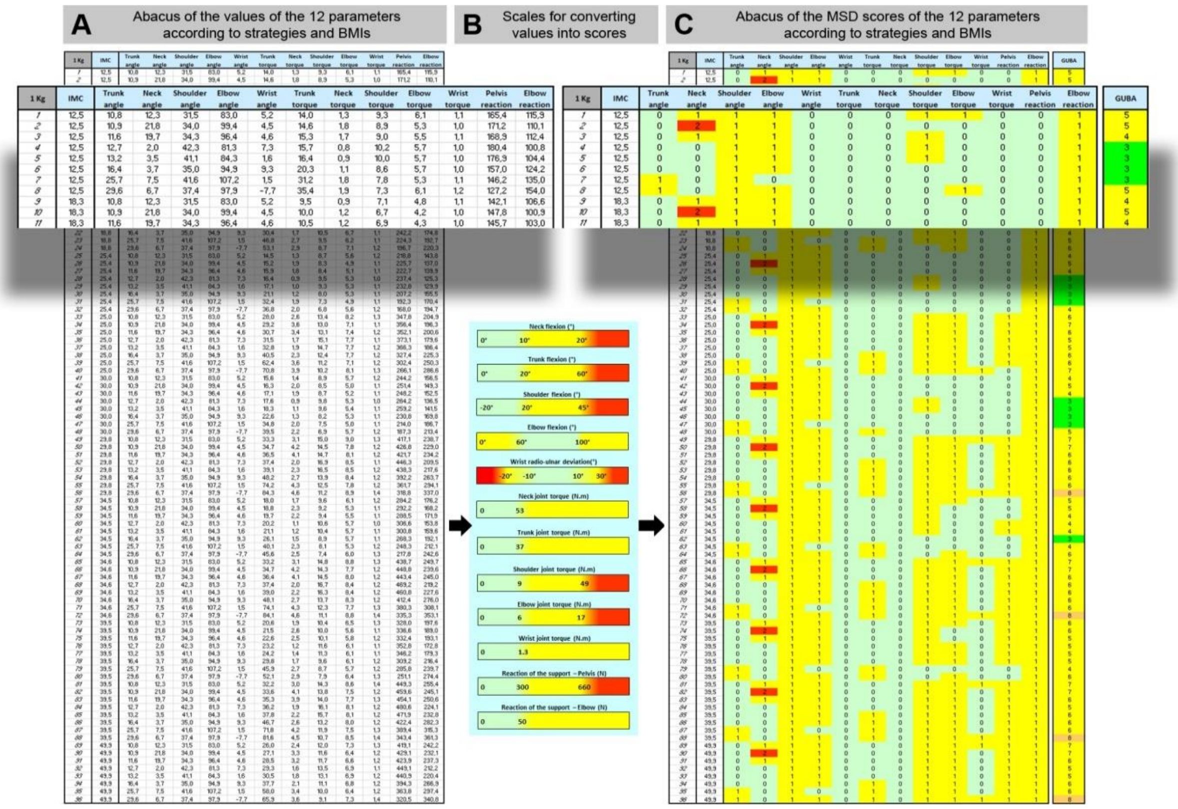


Figure 2. Table estimating the characteristic parameters of interaction with a smartphone in a seated position with the presence of a support (ST) and evaluation of the GUBA score.

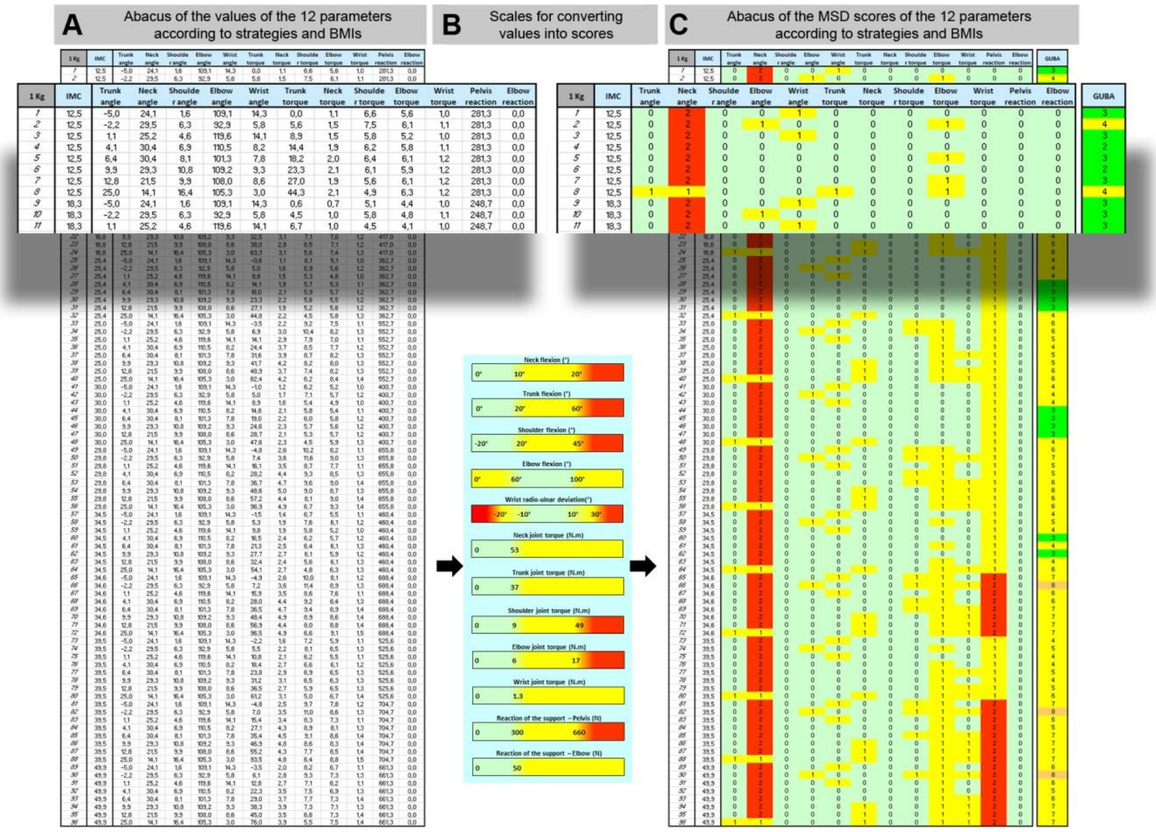


Figure 3. Table estimating the characteristic parameters of interaction with a smartphone in a seated position without support (SWT) and evaluation of the GUBA score.

The GUBA provides a score between 0 and 24, divided into six levels of risk of developing MSDs. The GUBA score is displayed in figure 2 and 3, panel C, last column. It takes into account the individual's anthropometric data (height and weight), posture and mass handled. Figure 4 shows the six levels of risk associated with the GUBA score and the corresponding colour code.

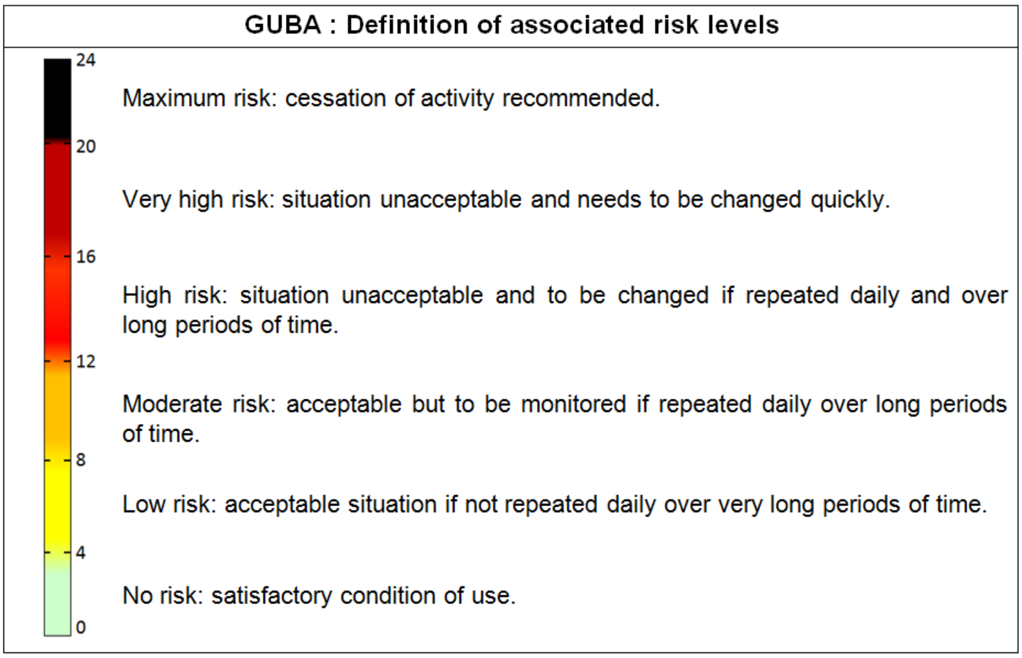


Figure 4. Risk level definition associated with the GUBA score.

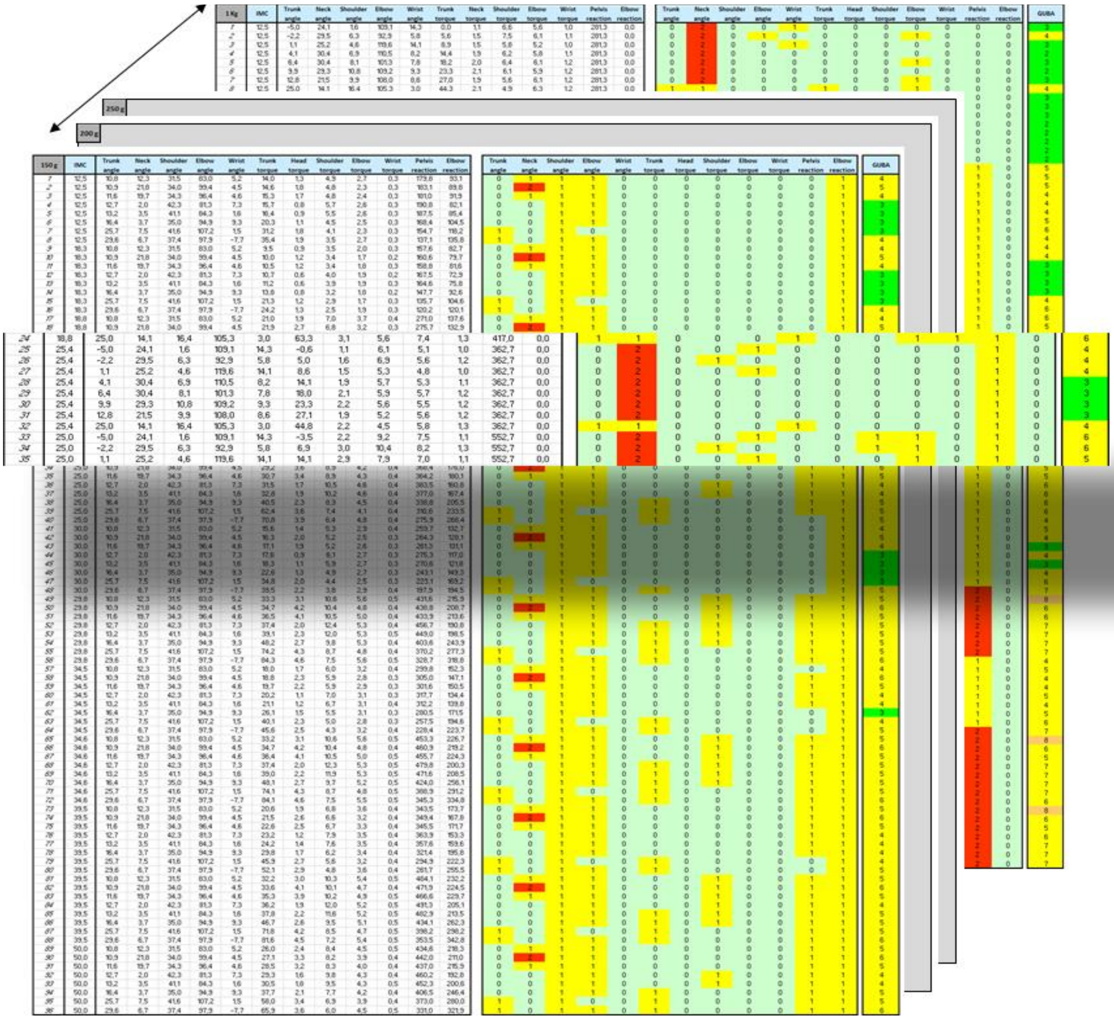


Figure 5. Illustration of the 21 abacus tables for the ST situation every 50 g.

Similarly to step 1, the MSD score and the GUBA score were generated with a 50 g increment to complete the abacuses for the two situations. This produced 21 tables for each situation. These two complete abacuses indicate the level of MSD risk according to the GUBA for handling light masses between 0 and 1 Kg in a seated situation, with and without support (figure 5).

RESULTS - APPLICATION

This section illustrates the use of the GUBA method based on abacuses. The examples selected for MSD assessment using GUBA correspond to situations involving interaction with digital devices: smartphones and handheld consoles. Three devices were chosen: a 150 g smartphone (model SAMSUNG Galaxy S10e), a 200 g smartphone (model HUAWEI P40 PRO) and a 400 g console (switch, Nintendo). Three different configurations (mass handled, BMI, and postural strategy) were considered with and without support:

- *Example ST1:* use of a 150 g smartphone by a seated user with a BMI of 30.0, with a support, and with a trunk strategy.
- *Example ST2:* use of a 200 g smartphone by a seated user with a BMI of 18.8, with a support, and with a mixed strategy.
- *Example ST3:* use of a 400 g smartphone by a seated user with a BMI of 39.5, with a support, and with a neck strategy.
- *Example SWT1:* use of a 150 g smartphone by a seated user with a BMI

of 25.0, without support, and with neck strategy.

- *Example SWT2:* use of a 200 g smartphone by a seated user with a BMI of 18.8, without support, and with neck strategy.
- *Example SWT3:* use of a 400 g smartphone by a seated user with a BMI of 39.5, without support, and with neck strategy.

The following steps are used to determine the GUBA score: 1) choose the abacus of the situation, i.e. sitting with or without support (ST vs SWT); 2) select the abacus corresponding to the mass of the object handled; 3) identify in the abacus the 8 lines corresponding to the user's BMI; 4) choose from the 8 postural strategies the one corresponding to the user's behaviour; 5) read the GUBA score at the end of the line. An example for the use of a 150 g smartphone by a user with a BMI of 30.0 sitting at the table for a trunk strategy is presented in figure 6. The GUBA score was read in the last column of the corresponding line (e.g. line 45 of the 150g abacus for SWT situation). For this situation, the GUBA score is 3. The abacus also provides the numerical values as well as the MSD scores for each parameter. The GUBA scores for the other example varied between 3 (No risk) and 6 (low risk). The highest GUBA score observed in all abacuses was 8 (with or without support when handling a mass of 1kg).

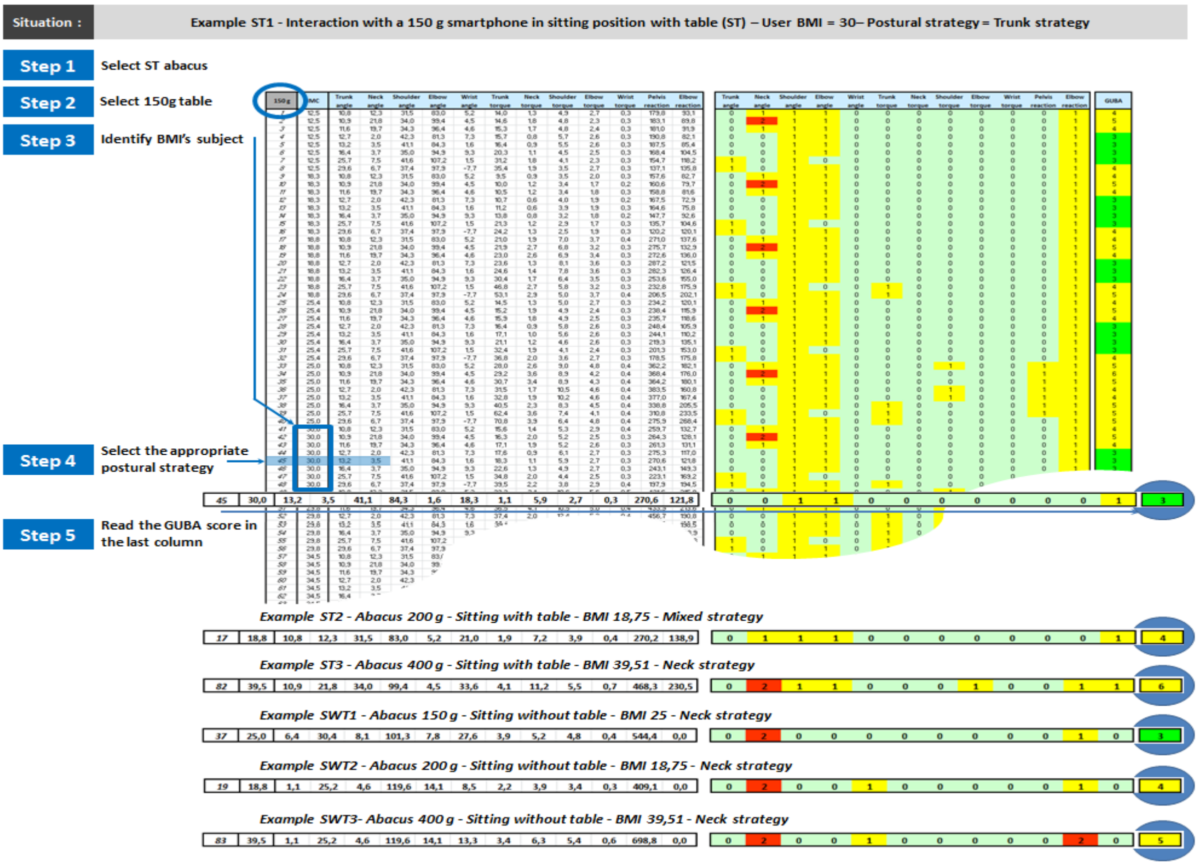


Figure 6. Example of use of the GUBA abacuses. Detailled example for a subject with a BMI of 30 with a trunk postural strategy when interacting with a 150g smartphone in a seated position with a table. The results of the 5 other example are displayed below.

DISCUSSION

The objective of this work was to present GUBA, a new ergonomic tool for assessing the MSD risks to individuals who interact with lightweight digital devices while seated. This tool uses abacuses to provide the MSD risk level, based on the user's anthropometric data, postural strategy and mass handled. The risk level depends on the GUBA score. This score was obtained from joint angles, joint torques and support reaction forces. The postural data for the trunk and upper limb matches those found in all ergonomic tools in the literature, such as RULA [13], REBA [14], LUBA [18], NERPA [19]. However, the integration of joint torques and support reaction forces in the assessment of MSD risks is an important original feature. Indeed, studies have shown that these parameters represent muscular activity considered as an important factor of appearance of MSDs [58,59]. In RULA, REBA, NERPA and LUBA, these are taken into account macroscopically. For RULA, REBA and NERPA, the impact of the load handled is only taken into account through a score between 0 and 3. There is no link with the consequences of the load on the musculoskeletal system, i.e. on joint or muscle torques. Furthermore, for these three tools, the presence of a support is weighted by an “arm postural score” of -1 point whereas in the GUBA, the presence of an arm support has its own risk scale depending on the reaction force value (low risk for a force less than 50N and medium risk higher than 50N). LUBA uses a composite index of perceived discomfort based on a posture (joint angles) and its corresponding maximum holding times in static postures.

In the GUBA tool, the joint torques were computed by the model taking into account the anthropometric characteristics of the subjects, unlike the other tools. These parameters weighted the scores obtained for the different joints by considering the mass of the segments involved. Thus, GUBA is sensitive to the morphology of the subjects and can modulate the risk level incurred by two individuals adopting the same posture but with different anthropometric characteristics. In the abacuses, when comparing the results for the same posture but a different BMI, the GUBA score increases with BMI. This can be explained by the increase in joint torques directly related to the increase in the subject's weight. This implies that subjects with a higher BMI generate higher joint loads which are directly related to an increase in discomfort and the appearance of pain. These GUBA score differences reveal different levels of risk, ranging from no risk (GUBA score of 3, green color) to low risk (GUBA score of 6, yellow colour) in the presented example and can reach 8 (moderate risk, orange colour) in the most unfavourable conditions.

Benefits and limitations

GUBA has the advantage of considering both supported and unsupported sitting positions. This is interesting from an ergonomic point of view, as studies have shown that the presence of a support is a good way of reducing the MSD risk [38,60]. However, in their current version, the GUBA abacuses are based on a fixed table and chair height. It would be interesting to be able to change these parameters, as they have a direct impact on posture, and therefore on reaction torques and forces, and consequently on the risk of MSDs. The abacuses were also constructed from 12 BMIs covering the extremes of each zone (underweight, normal weight, overweight, and obesity class I to III), i.e. high height with low weight and low height with high weight, in order to limit the number of combinations. This made it possible to propose an estimate based on each BMI zone. This choice does not include intermediate combinations that could correspond to median individuals in each zone. However, by taking the closest combination, the abacuses can give an estimate for any individual. More combinations could be considered in the future.

GUBA incorporates thresholds for posture, joint torques and support forces into its computation. With regard to posture, the thresholds presented are in line with those of RULA, which is the most widely used ergonomic tool and presents the best MSD risk assessments [61]. Only the wrist thresholds have been modified. Indeed, when handling a two-handed handheld device, the mobility that enables the screen to be oriented in relation to the gaze is radio-ulnar deviation, not flexion/extension. However, only flexion/extension values are presented in RULA. Threshold values for the wrist were derived from LUBA [18], which provides joint discomfort thresholds based on muscular loadings for radio-ulnar deviation. However the GUBA posture was modeled using the same 2D principle as other ergonomic tools (RULA, REBA, LUBA, and NERPA)., It is well known that movements with lightweight devices such as smartphones [32] or tablets [62] are performed in all 3 planes. Future work could be carried out to build an ergonomic tool with a 3D assessment of posture rather than simply weighting the existence of movement in a plane other than the sagittal plane.

With regard to joint torques, numerous studies have attempted to determine acceptable muscular loads during an activity, particularly at work. The underlying question was what would be the acceptable load that could be applied over a long period corresponding to a day's work. Thresholds were usually defined as a fraction of the maximum load obtained from a MVC expressed in Newtons. The values presented in the literature vary and depend on the duration tested and the mode of contraction. Thresholds of 15% MVC have been reported for 10 min sustained static exercise [48], 7.9% for one hour or 14% for one hour intermittent static exercise [50]. Although there is no consensus as reported by El ahrache et al. on maximum endurance time [63], authors agree that when physiological impairment of muscle function is observed, maintenance time is drastically reduced [48,49]. Jørgensen et al. (1988) showed a reduction in MVC (12%) and mean spectral frequency of the EMG-power spectrum of several muscle groups after one hour's continuous contraction at 5% MVC [49]. During intermittent static contraction (10 s contraction and 5 s rest) for 7 hours, the same authors showed a reduction in spectral frequency of the same muscle groups at 14% MVC, which did not occur at 10% MVC. To our knowledge, there are no equivalent values for joint torques. A similar approach was taken using the maximum torques reported in the literature. As far as the choice of threshold is concerned, interaction with a tactile device is similar to intermittent static activity. The user is free to change posture when the need arises. Based on the work of Jørgensen [49] and Bjørksten [50], the value of 10% was chosen as the first threshold below which the risk of MSD is low. However, in these studies, threshold values were defined for isolated muscle groups (such as elbow, finger or knee flexors). It would be useful to take a more in-depth analysis, considering all the muscle groups associated with a posture, and adapt the threshold value to each muscle group if necessary. Defining the second threshold value of the GUBA scale was more difficult. For the shoulder and elbow, indirect data made it possible to define a threshold based on relationships between subjective data scales and joint angles. No data could be defined for the extensor muscles of the spine (neck and trunk). Given GUBA's scope of application, these muscles are only used for posture maintenance. The torque values computed are relatively low in relation to their maximum capacities. It is highly unlikely, even with the most unfavourable BMI, to reach a level of solicitation sufficient to cause a high risk of MSD. For the wrist, despite a lower maximum capacity than the spinal extensors, the load handled is low (<1kg). Added to the mass of the hand, the load is also not sufficient to reach the high risk. However, further work is needed to assess these thresholds and thus refine the GUBA risk computation.

Thresholds for support reaction forces for the seat have been defined on the basis of the average seat surface reported in the literature and associated physiological data (tissue compression and physiological alterations). However, these thresholds can be modified according to the nature, shape and thickness of the seat. An interesting approach would be to study the effect of these parameters on the thresholds, so that they can be adapted in the model.

In its current state, the GUBA is valid for the handling of very light loads (0-1kg). Further studies are to be carried out in order to refine the model used to include larger loads and thus extend its scope of application.

CONCLUSION

The aim of this article is to present a new rapid assessment method, called GUBA, which can be used to obtain a score to assess the level of risk of MSD occurrence. The proposed field of application is that of a light mass of between 0 and 1 kg in a seated position with and without support, in the context of the use of digital devices. The GUBA tool was developed in three stages: 1) modeling to quantify joint parameters, joint torques and reaction forces; 2) development of risk scales; 3) calculation of the GUBA score. A set of abacuses has been created to enable the user to directly read the GUBA score and the corresponding MSD risk level. The abacuses are very easy to use: simply select the abacus for the situation (ST vs SWT), choose the table corresponding to the mass handled, identify the user's BMI, choose the postural strategy, and finally read the GUBA score at the end of the line.

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