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RELIABILITY AND VALIDATION OF TWO DIFFERENT ANGLE ESTIMATION METHODS

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INTRODUCTION:

Occupational trunk posture has been associated with musculoskeletal health [1]. Posture related risk factors for low back pain include bending, twisting, and prolonged static postures. Consequently, the measurement of postures is important to evaluate exposure and to allow the establishment of exposure limits to certain risk factors [2]. Few methods for measuring postures in the field are available in musculoskeletal studies. The choice of exposure assessment techniques largely depends on the exposure of interest as well as the validity, reliability, and resolution of the instrument [2].

The purpose of this study was twofold. First, the reproducibility of determining joint angles from video data was evaluated for a symmetrical lifting and lowering task. The second component of the present study was to compare maximum flexion-extension trunk angles evaluated during the same task using two methods: a) digitizing snapshots from video recordings and b) measuring angles from an inclinometer system (Virtual Corset™ by Microstrain, Vermont, USA).

It is expected that the results from the current study will help identify some of the strengths and weaknesses of two forms of data collection methods, using inexpensive instruments that can be implemented in the field in remote environments.

METHODS

Twenty pregnant women and 24 non-pregnant women, recruited for a previous study, were included in the current study. All subjects were street merchants and were recruited in Port-Novo, Benin, the pregnant women from a community maternity centre, and the non-pregnant women through local contacts. The participants were instrumented with a Virtual Corset attached to the body using a harness at the C7 level to obtain the inclination angle of the upper trunk. Video data were collected with a digital camera (Sony HandyCam DCR-SR82) set on a tripod at 1 m above ground and located at 5 m from the subject and parallel to her sagittal plane. The task consisted of lifting a tray from a stool to place it on the head, walk for 6 meters and place the tray back on the stool.

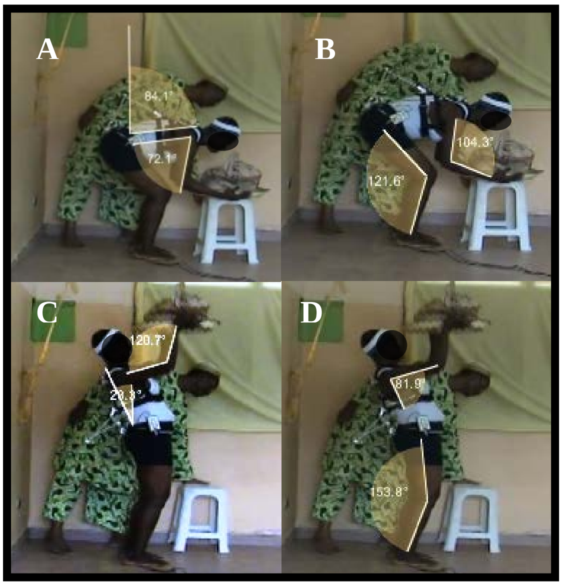

Figure 1: Representation of joint angle definitions in each posture. A & B) Trunk angle with respect to global vertical, shoulder, elbow and knee angles at maximum trunk flexion. C & D) Trunk angle with respect to global vertical, elbow, shoulder, and knee angles at maximum trunk extension.

For the first part of the study, data from a subset of 10 participants selected based on their subject code (odd numbers) were evaluated. Two postures were isolated from the task: maximum flexion and maximum extension of the trunk. In the context of the task, the flexion posture was defined as the most flexed posture when the participant picked up the load, and the extension posture was defined as the most extended posture when the participant was placing the load on her head. Four joint angles were considered (Figure 1).

Dartfish software was used to estimate joint angles from digital video recordings. Two different researchers digitized each joint angle three times [3]. Intraclass correlation coefficients (ICCs) were determined from the digitized angles to assess the level of reliability.

For the second part of the study, the full sample was included. In order to ensure that the data collected from the inclinometer and that estimated from video data were representing the same angle, i.e. the angle of the upper back with respect to vertical, the same segment measured by the inclinometer was digitized rather than whole trunk inclination angle (Figure 2). This joint angle was compared to the angle outputs obtained from the inclinometer. From this comparison, Bland and Altman[6] plots were created in order to find the level of agreement between the inclinometer data and the digitized angle data.

Figure 2: The upper trunk angle measured in both maximum flexion and extension.

RESULTS AND DISCUSSION

The first objective for this study was to evaluate the intra-rater reliability for digitizing joint angles from a recorded video data. The results showed that there was a high level of repeatability within each rater, with all ICC values ranging from 0.795 to 1.000 for all analyses, except one (the shoulder, rater 1 (ICC=0.393)). An analysis of inter-rater reliability for the two raters showed a strong to very strong agreement for every comparison with ICCs ranging from 0.62 to 0.98 (Table 1).

Table 1: Mean ICC values and standard deviation (N=10).

Because inconsistent assessment scores are difficult to interpret meaningfully and thus reduce validity of the data,

		ICC $^{\varphi}$	
	Segment	**Flexion**	**Extension**
Raters 1 & 2 (Non-Preg)	Trunk*	0.963	0.959
	Knee	0.981	0.625
	Elbow	0.617	0.869
	Shoulder	0.728	0.779

* Trunk segment with respect to the global vertical axis.
$^{\varphi}$ All comparisons are significant ($\alpha = 0.05$)

the reliability coefficients obtained in this analysis are encouraging. This analysis has shown that, when trained by the same individual, multiple raters are able to digitize the same points. This is useful in data processing situations, as multiple raters will help to increase data processing speed without introducing new sources of error.

The second objective for this study was to compare the level of agreement between the angles obtained from the Virtual Corset (VC) data and the digitized video data. The results from a Bland-Altman analysis of the data obtained using the two methods showed a low systematic bias and narrow limits of agreement for the non-pregnant group and the pregnant group at maximum extension only (Table 2). The angles measured with the VC were larger than those measured on the videos except for maximum extension in the pregnant group. Similarly, in a previous study comparing data collected with a VC and with a motion capture system for trunk posture [4], a good agreement was seen between the two instruments.

Table 2: Bias and limits of agreement (degrees) from Bland and Altman [6] plots for maximum trunk flexion and trunk extension angles.

Group	Angle	Bias	Limits of agreement
Non-Pregnant	Flexion	1.7	-10.0 to 13.5
N = 24	Extension	1.9	-8.1 to 11.8
Pregnant	Flexion	7.1	-4.2 to 18.4
N=20	Extension	-4.0	-18.0 to 10.1

It is unclear why the agreement between the two methods is substantially better in the non-pregnant than in the pregnant group. It is possible that there are problems related to heteroscedasticity where the scatter of the differences increases as the angle magnitude increases [5]. However, no larger effect could be observed for the pregnant group data by inspection of the plots. A log transformation of the data may correct these problems, but would make data interpretation less straightforward [6].

Possible limitations for the current study surround the choice of instrumentation. The quality of the video recordings used in this analysis can only be classified as moderate in terms of resolution and lighting however, while the quality of the video data may not have been ideal, it did not appear to interfere with the researchers' ability to identify key joint landmarks. Additionally, accelerometers (such as the VC) are known to be prone to errors due to large accelerations when used as inclinometers in dynamic postures; however, in this study, a good agreement was found between VCs and videos data in 3 of the 4 cases considered. Thus, while criticisms can be made as to the quality of the data analyzed, the purpose of the present study was to validate these methods. As the results showed that these methods are reliable under sub-par conditions, it can be said that these methods would be a good choice for laboratory and field studies where the availability of high quality equipment may be limited.

CONCLUSIONS

This study demonstrated that digitizing body segments and computing joint angles using the Dartfish software can be highly repeatable. In addition, comparisons between inclinometer and digitized data showed some agreement, however further investigation is required in order to determine the source of the discrepancies observed in this analysis.

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