In Vivo Measurement of Humeral Elevation Angles and Exposure Using a Triaxial Accelerometer

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Objective: The aim of this study was to measure the capability of a triaxial accelerometer (Virtual Corset) to collect humeral elevation angles and exposure parameters in a simulated occupational environment.

Background: There is a need for an economical ambulatory device to estimate elevation angles and exposure parameters in occupational groups.

Method: A magnetic tracking device was used to assess the ability of the Virtual Corset to evaluate humeral elevation angles and identify exposure parameters with in vivo dynamic conditions for 16 female dental hygienists.

Results: Significant differences were found for the reaching task with the Virtual Corset, underestimating the means of the average humeral elevation angle by 10° and the means for the range of the humeral elevation by 4°. Furthermore, significant differences were found for the exposure parameters with the Virtual Corset, overestimating the jerk by 4% and underestimating the percentage time above 40° and 60° by 9% and 4%, respectively. However, the Virtual Corset was able to identify similar kinematics patterns and exposure data when compared with a magnetic tracking device.

Conclusion: The outcomes of the study suggest that the Virtual Corset may be useful for data collection during a dental hygienist workday. Professions that have similar patterns of angular velocity and acceleration and humeral range of elevation as the dental hygienist flossing technique may benefit from the use of the Virtual Corset.

Application: This study provides evidence that the Virtual Corset can be used to reconstruct humeral elevation angles and identify exposure parameters in some tasks of dental hygienists.

Keywords: models and measures, dental hygienist, upper extremity and shoulder, triaxial accelerometer, humeral elevation angles, ambulatory device

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INTRODUCTION

In recent years, there has been a dramatic rise in the number of occupational shoulder injuries (Sommerich, McGlothlin, & Marras, 1993), with the Bureau of Labor Statistics in the United States reporting that for the most recent data set available (2007), shoulder problems account for almost 76,000 occupational injuries involving days away from work annually (Bureau of Labor Statistics, 2008). The event and joint that resulted in the longest absences from work were repetitive motion and the shoulder, respectively (Bureau of Labor Statistics, 2008). Although the underlying mechanisms of occupational shoulder injuries have not been well established, a comprehensive review by the National Institute for Occupational Safety and Health has found evidence for positive relation between musculoskeletal disorders of the shoulders and highly repetitive work (Bernard, 1997). These injuries have an enormous financial impact, given the use of health care services, lost workdays, and worker disability costs.

Numerous investigators have assessed upper-extremity motion in an attempt to quantify workers' exposures to risk factors for musculoskeletal disorders (Fernstrom & Ericson, 1996; Moller, Mathiassen, Franzon, & Kihlberg, 2004; Punnett, 1998; Sporrong, Sandsjo, Kadefors, & Herberts, 1999; Svendsen, Gelineck, et al., 2004; Vasseljen & Westgaard, 1997). Svendsen, Bonde, Mathiassen, Stengaard-Pedersen, & Frich (2004) and Svendsen, Gelineck, Mathiassen, Bonde, Frich, Stengaard-Pedersen, & Egund (2004) found that workers exposed chronically to arm elevation angles higher than 90°, with respect to gravity, were more susceptible to shoulder injury, whereas Punnett, Fine, Keyserling, Herrin, and Chaffin (2000) identified the shoulder angle of 90° with respect to the trunk.Ohlsson et al. (1995) found this threshold to be 60°.

Three main physical risk factors for upper-extremity musculoskeletal disorders have been identified: force (intensity and duration), repetition, and posture (awkward and constrained) (Bernard, 1997). The measurement of occupational exposures in field settings is very challenging. Three methods are frequently used to determine exposure levels. The first two methods, survey and observational, are subjective, whereas the third method, direct measurement, is objective and provides more precise measurements (David, 2005; Li & Buckle, 1999).

Accelerometers are commonly used to estimate elevation angles for the upper extremity (Bernmark & Wiktorin, 2002; Estill, MacDonald, Wenzl, & Petersen, 2000; Hansson et al., 2006; Hansson, Asterland, Holmer, & Skerfving, 2001; Mathiassen, Moller, & Forsman, 2003; Moller et al., 2004). However, several of these devices have limitations attributable to their construction. Some are cumbersome because of their dependence on hardwired cables connecting the transducers and the data logger. Others have a limited measuring range of motion and/or sampling rates. In addition, most of these devices are not available commercially.

The Virtual Corset is a triaxial accelerometer that has been previously validated in static and dynamic conditions (Amasay, Zodrow, Kincl, Hess, & Karduna, 2009). In static conditions, the root mean square (RMS) error was less than 1°, whereas in dynamic conditions, the Virtual Corset is sensitive to angular velocity and acceleration along with the radius. The calculated angle error increased as the radius, angular velocity, and angular acceleration increased (Amasay et al., 2009). To the best of our knowledge, this device has not been validated with in vivo conditions, which led us to the present study's question: How well can the Virtual Corset estimate elevation angles and exposure parameters in an occupational group relative to a magnetic tracking device? We have selected dental hygienists as an appropriate population because of the high prevalence (11% to 68%) of musculoskeletal disorders in this population (Akesson, Johnsson, Rylander, Moritz, & Skerfving, 1999; Liss, Jesin, Kusiak, & White, 1995; Morse et al., 2007; Werner et al., 2005; Werner, Hamann, Franzblau, & Rodgers, 2002).

METHOD

Participants

For this study, 16 female dental hygienists with a mean age of 50 years (28 to 64 years), height of 167 cm (157 to 175 cm), and body mass of 71 kg (56 to 84 kg) were recruited. Inclusion criteria required practicing dental hygienists with a minimum of 1 year of work experience (actual experience range was 1.5 to 32 years). Exclusion criteria consisted of impairments in arm elevation range of motion (less than 120° of humeral elevation), current injuries to the shoulder or back, any history of upper extremity surgery during the past 2 years, and any diagnosed neurological disorders. Prior to participation, all participants signed an informed consent form approved by the university's institutional review board.

Instrumentation

Humeral elevation angles were collected simultaneously with the Liberty magnetic tracking device (Polhemus, Colchester, VT) and the Virtual Corset (Microstrain, Williston, VT). The magnetic tracking device consisted of an electronics unit, a transmitter, one sensor, and one digitizer. This device was interfaced with the Motion Monitor software program (Innovative Sports Training, Chicago, IL). Data were collected at a rate of 120 Hz per sensor. The transmitter emitted an electromagnetic field that was detected by the digitizer and the sensor. The device's electronic unit determined the relative orientation and position of the sensors in space. The Virtual Corset is a pager-sized (6.8 cm × 4.8 cm × 1.8 cm), battery-powered, triaxial accelerometer with an integrated 2 Mb data logger, with a total weight of 72 g and no associated cables. This device is constructed from two dual-axis accelerometers, ADXL202E (Analog Device, Norwood, MA) ±2g and 0.2% nonlinearity, with a sampling rate of approximately 7.6 Hz, and a low pass filter with a cutoff frequency of 10 Hz. For both systems, data analysis was performed using LabView software (National Instruments, Austin, TX).

A simulated working station was created in the testing laboratory, which consisted of a dental hydraulic chair, dental light, and dental hygienist stool. A custom-made manikin with dentures (Dental Hygiene Model M-YNR-1560, Colombia Dentoform Corp., Long Island City, NY) was secured to the dental chair with the use of a strap. The simulated workstation was modified to reduce error by replacing the dental chair metal head support with wood; also, the manikin, used as a replacement for a patient, was made out of fiberglass. The cumulative error in the simulated workstation on the magnetic tracking device was found to be approximately 1.4°.

Setup and Digitization

Bony landmarks were digitized to define anatomically based coordinate systems for the scapula and humerus. A magnetic tracking sensor was placed on the participant's dominant arm just above the medial and lateral epicondyles with the use of a customized molded cuff attached by Velcro strips. A global coordinate system was established by mounting the transmitter on a rigid plastic base. The transmitter was located behind the participant at the humeral sensor height, at a horizontal distance of 30 cm from the trunk.

Participants were in their natural standing position during digitization. Anatomical landmarks were digitized for the scapula (root of spine of the scapula, acromial angle and inferior angle) and the humeral coordinate systems (medial and lateral epicondyles and ulnar styloid process). The arbitrary axes defined by the magnetic tracking device were converted to anatomically appropriate embedded axes derived from the digitized bony landmarks. The mathematical conversion of the arbitrary axes to anatomical axes was based on the International Society of Biomechanics second recommendation for the humerus, taking the ulnar styloid process as the third point for the plane, with the elbow in 90° of flexion (Wu et al., 2005). All landmarks were surface points and, therefore, could be located directly, except for the center of the humeral head. To locate the center of the humeral head, another sensor was placed on the scapula. The center of the humeral head was defined as the point on the humerus that moves the least with respect to the scapula while moving the humerus through short arcs (<45°) of midrange glenohumeral motion and was calculated using a least-squares algorithm (Veeger, 2000). After the digitization process, the raw data from the sensors were converted into anatomically defined rotations that could be displayed in real time with the use of MotionMonitor software.

Standard matrix transformation methods were used to determine the rotational matrix of the humerus with respect to the global coordinate system. In the global coordinate system, the *Z*-axis was aligned with the line of gravity and not with the trunk. Humeral rotations were represented with the use of a standard Euler angle sequence (Y-X'-Y") in which the first rotation defined the plane of elevation, the second rotation described the amount of elevation, and the last rotation represented the amount of internal and external rotation. In the current study, only the humeral elevation angles were analyzed. Humeral elevation angles measured by an accelerometer are measured with respect to the line of gravity. Therefore, to compare between the two devices, the humeral elevation measured by the magnetic tracking device was also reported with respect to the global coordinate system.

Following the digitization procedure for the magnetic tracking device, the Virtual Corset was mounted on the lateral side of the humerus just above the deltoid tuberosity with the use of a double-sided adhesive tape and was secured in place with the use of an underwrap pretaping foam (Mueller Sports Medicine, Prairie du Sac, WI) (Figure 1). The distance from the Virtual Corset to the shoulder center of rotation had to be estimated to predict elevation angle errors as a result of dynamic motion. The center of the glenohumeral joint was estimated to be 3.1 cm below the acromion process with 2.3 cm as the average humeral head radius (McPherson, Friedman, An, Chokesi, & Dooley, 1997) plus 0.8 cm as the average height of the subacromial space (Graichen et al., 2001). The distance from the lateral aspect of the acromion process to the apex of the Virtual Corset was registered by a measuring tape. Subtracting the 3.1 cm from the Virtual Corset–acromion distance was assumed to be the accelerometer's radius of rotation. The center of the glenohumeral joint was assumed to be the instantaneous center of rotation of the humerus with respect to the global coordinate system.

The elevation angle relative to the line of gravity for the Virtual Corset and magnetic tracking device (zero gravity) were taken at the beginning of the testing. The participants were in a

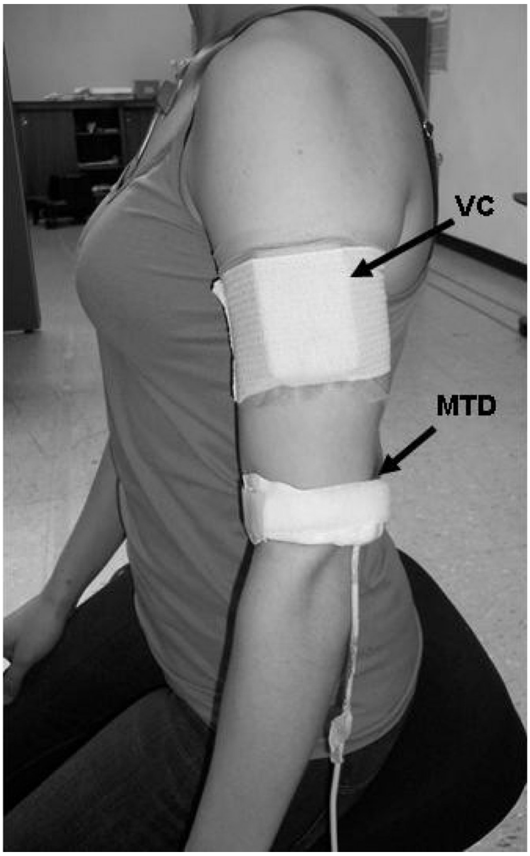

Figure 1. Placement of the Virtual Corset (VC) relative to the magnetic tracking device sensor (MTD).

seated position holding a 1.1 kg weight in their dominant hand. They were instructed to bend their trunk laterally, with their dominant upper extremity hanging down freely (Hansson et al., 2006). At this position, the arm was assumed to be aligned with gravity.

Experimental Procedure

All testing was completed in a single session. Participants started the experiment with a standardized warm-up procedure for the shoulder, including Codman's pendulums and stretches for the rotator cuff muscles for both arms (Amasay & Karduna, 2009). Following the warm-up procedure, participants removed any object that would interfere with the magnetic tracking device data collection, such as jewelry and belts.

To quantify the ability of the Virtual Corset to identify exposure parameters in dental hygienists relative to the magnetic tracking device, data were collected in two conditions, reaching and flossing (Figure 2). Data from the Virtual Corset were collected on its data logger, and data from the magnetic tracking device were collected through the USB port on a computer, which makes the synchronization of the two devices difficult. For both conditions, the participant started with a synchronization task that was followed immediately by one of the conditions. The synchronization task involved participants moving their arm back and forth 10 times (like a pendulum) in the sagittal plane at a pace of approximately 60 beats per minute (paced with a metronome). The two devices were synchronized by matching the peaks for each cycle of shoulder elevation. A cross-correlation analysis was run to check the synchronization for all participants. For each participant, the highest correlation coefficient found was above 0.94 at zero lag (Figure 3).

In the first condition following the synchronization task, participants were in an upright standing position and performed a reaching task to a shelf at head height. The target was located in the sagittal plane at a horizontal distance of 80% of arm length and height of 50% of arm length above shoulder height. The target location was standardized and normalized for each participant on the basis of anthropometrical measurements that were taken from each participant with a measuring tape (Amasay & Karduna, 2009). For the flossing task, participants were in a seated position in the simulated workstation and were instructed to perform full-mouth flossing with the technique used in their daily work routine (Figure 2B). Each task was performed twice.

Data Reduction and Statistical Analysis

The Virtual Corset is a linear triaxial accelerometer, and therefore, any linear acceleration acting on the device besides gravity will result in an error of the predicted elevation angle. To predict the error caused by linear acceleration, the angle between the actual linear acceleration resultant and gravity acceleration vectors was calculated. Arm motion is an angular motion; therefore, the resultant linear acceleration is the sum of gravitational, radial, and tangential acceleration vectors. The product of the angular velocity squared and the radius is the radial acceleration, and the tangential acceleration is the product of

Figure 2. Reaching (A) and flossing (B) tasks.

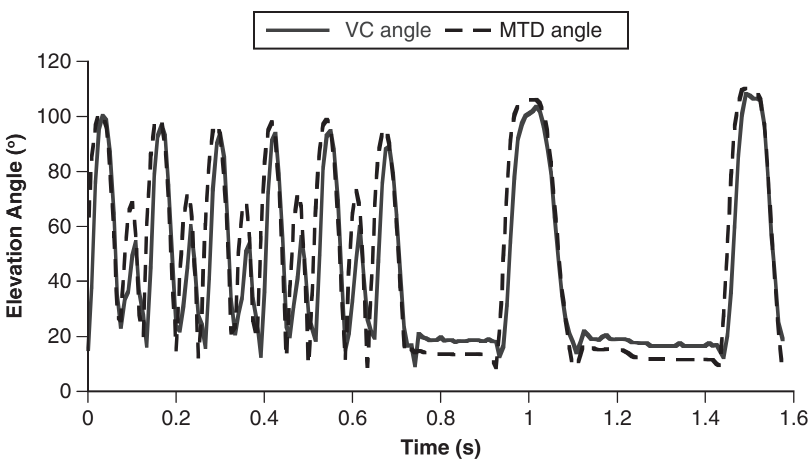

Figure 3. The synchronized pendulum motion followed by the two reaching tasks of the Virtual Corset (VC) and the magnetic tracking device (MTD).

the angular acceleration and the radius. The Virtual Corset angle error for each task was predicted with the use of angular data collected via the magnetic tracking device and Equation 1, which was validated in a prior study (Amasay et al., 2009). The error (β) was estimated as a function of the angular position (θ), velocity (ω) and acceleration (α) and distance from the Virtual Corset to the axis of rotation (r):

$$\beta = \sin^{-1}\left[\frac{\alpha r\cos\theta - \omega^2 r\sin\theta}{\sqrt{(\alpha r + g\sin\theta)^2 + (\omega^2 r + g\cos\theta)^2}}\right] \quad (1)$$

To quantify the differences in elevation angles between the Virtual Corset and the magnetic tracking device in the reaching task, participants' range and average humeral elevation angles were calculated. A paired *t* test was conducted to determine whether there was a significant difference between the two devices. The data of the two reaching trials were averaged prior to data analysis.

In the flossing task, exposure parameters were used to compare between the two devices. The chosen exposure parameters were jerk analysis and percentage time above 20°, 40° and 60° of arm elevation. The jerk is a parameter describing the repetitiveness of a task and was defined as the percentage of the cycle time spent in time sequences shorter than 1 s within the same exposure bin of 10°. A larger jerk value indicates a more dynamic exposure pattern (Mathiassen, Burdorf, van der Beek, & Hansson, 2003; Moller et al., 2004). A paired *t* test was conducted to determine whether there were significant differences for the jerk variable between the two devices. The data from the two flossing trials were averaged before performing a separate two-way ANOVA with repeated measures, with percentage time above arm elevation angle as the dependent variable and two independent variables. The independent variables were device (Virtual Corset and magnetic tracking device) and position (20°, 40°, and 60°). Also, a Pearson correlation test was run to assess correlation between the two devices. Intrasubject repeatability of these different dependent variables was quantified with the intraclass correlation coefficient, ICC [3, 1], and standard error of measurement (*SEM*).

RESULTS

Averaged across participants, the zero gravity position measured by the Virtual Corset and the magnetic tracking device were 6.7° (SD = 3.8°) and 8.3° (SD = 4.7°), respectively. Equation 1, which predicts the Virtual Corset elevation angle error, predicted the averaged RMS angle error for the reaching and flossing tasks to be 5.1° and 1.3°, respectively. Intrasubject ICC values for the dependent variables ranged from .61 to .99, indicating good to high reliability (Table 1).

Significant differences were found in the reaching tasks for the average humeral elevation angles (p < .001) and the range of humeral elevation (p = .019) between the Virtual Corset and the magnetic tracking device. The means for the averaged humeral elevation angle of the Virtual Corset and the magnetic tracking device were 56° and 66°, respectively. The means for the range of the humeral elevation of the Virtual Corset and the magnetic tracking device were 95° and 99°, respectively. High correlation (r = .85) was found for the averaged humeral elevation angle and moderate correlation (r = .44) for the range of humeral elevation (Figure 4).

For the flossing tasks, a significant difference was found for the jerk parameter between the two devices (p = .05). The means for the jerk parameter of the Virtual Corset and the magnetic tracking device were 26% and 22%, respectively, with a moderate correlation (r = .46). No interaction was found between the devices and position (p = .30); however, the main effect was significant for both independent variables, device (p = .001) and position (p < .001). A post hoc paired *t* test with Bonferroni correction was conducted for the device variable. Significant differences were found between the Virtual Corset and the magnetic tracking device in percentage time above 40° (p = .005) and percentage time above 60° (p = .001), whereas no significant differences (p = .062) were found at percentage time above 20° (Figure 5). High correlations (.84 to .96) were found for all the three position levels.

DISCUSSION

The Virtual Corset has previously been validated and has shown promising results for the reconstruction of humeral elevation angles. It has been found that the Virtual Corset RMS angle error in static conditions was less than 1°, with maximal angle difference error less than 2°. However, in dynamic conditions, the size of the error was related to the angular velocity and acceleration and the radius (Amasay et al., 2009).

TABLE 1: Mean and Intrasubject Reliability for the Dependent Variables of the Reach Task and the Floss Task

	Virtual Corset			Magnetic Tracking Device		
Task	*M*	ICC	*SEM*	*M*	ICC	*SEM*
Reach						
Average (°)	56.4	0.7	3.6	65.8	0.71	3.8
Range (°)	95.2	0.96	1.3	99.3	0.74	2.5
Floss						
Jerk (%)	25.9	0.61	4.5	21.9	0.71	4
% time above 20°	71.9	0.99	2.4	78.6	0.99	2.1
% time above 40°	25.8	0.96	4.4	35.2	0.96	5.3
% time above 60°	7.8	0.87	2.6	11.7	0.9	3.3

Note. ICC = intraclass correlation; average = average humeral elevation angle; range = range of humeral elevation.

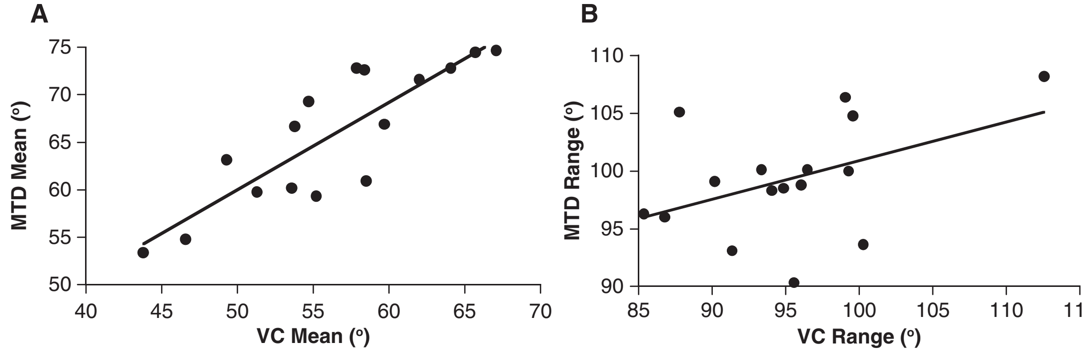

Figure 4. Average (A) and range (B) of humeral elevation angles correlation between the Virtual Corset (VC) and the magnetic tracking device (MTD) in the reach task.

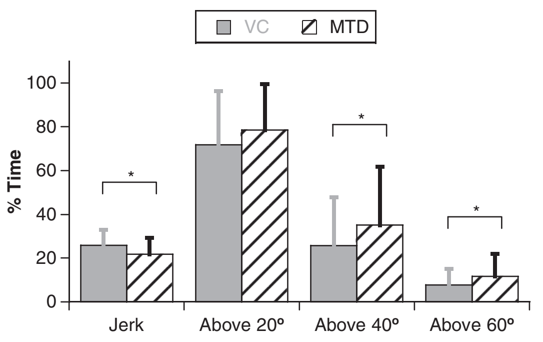

Figure 5. Averages of the exposure parameters used to analyze the flossing task. *$p < .05$.

The distance between the Virtual Corset and the axis of rotation (radius) dictates the size of the error. It was found that the larger the radius, the larger the angle error; as the radius increases, the tangential and radial accelerations increased as well. Similar results were found for angular acceleration and velocity, whereas plane of elevation did not increase the angle error (Amasay et al., 2009).

Measuring ballistic motions, such as baseball pitching, using the Virtual Corset is not practical as a result of a high internal rotation peak angular velocity of 8000°/s (Werner, Gill, Murray, Cook, & Hawkins, 2001) and a peak angular acceleration of 25,000°/s^2 (Hirashima, Kudo, Watarai, & Ohtsuki, 2007). This angular acceleration is close to 200 g, which is beyond the Virtual Corset's measurement capacity of 2 g. Estimating maximum angle error for this motion revealed an error close to 90°. At lower angular velocities and accelerations, the Virtual Corset may be appropriate for measuring occupational exposure. When reaching for an object across the shoulder or at head height, the RMS angle error was found to be 3° (average angular velocity of 54°/s and acceleration of 314°/s^2) and 5° (average angular velocity of 106°/s and acceleration of 554°/s^2), respectively, with a radius of 10 cm (Amasay et al., 2009). For each task or job for which data collection is needed, it is advisable to use Equation 1 to estimate angle errors, which can assist in determining how appropriate the Virtual Corset is for that application.

To the best of our knowledge, the capability of the Virtual Corset to assess humeral elevation angles and identify exposure parameters in vivo has not previously been evaluated. In the current study, the Virtual Corset was tested with in vivo dynamic conditions. Specifically, dental hygienists were tested while performing both reaching and flossing tasks with both the Virtual Corset and a magnetic tracking device. The ICCs for the dependent variables used in the study were found to be good to high, and the *SEM*s were low. This indicated a good repeatability for the study dependent variables.

For the reaching task, significant differences were found for the mean and range of humeral elevation angles. The average angle differences for the mean and range of humeral elevation were 10° and 4°, respectively. Equation 1 predicted the average RMS angle error for the reaching task to be 5.1°. The difference between the Virtual Corset and the magnetic tracking device at the average zero gravity position was 1.6°. At the zero gravity position, the expectation was that the two devices would read 0° if the humerus was aligned with gravity. However, the Virtual Corset on average read 6.7°, and the magnetic tracking device read 8.3°.

Both the magnetic tracking device sensor and the Virtual Corset are surface sensors, and one of the main sources of error when using surface sensors methods to measure humeral kinematics is skin artifact. Ludewig, Cook, and Shields (2002) found an RMS error of 3.1° for humeral elevation angles with the use of the surface-mounted magnetic tracking sensor. In the present study, the sensor of the magnetic tracking device was located above the epicondyles, whereas the Virtual Corset was located close to the deltoid tuberosity; therefore, soft tissues artifact might be different between the locations. The Virtual Corset coordinate system is based on the device, which would be influenced by participants' upper-arm morphology and the placement of the device. Conversely, the magnetic tracking device coordinate system was based on a humerus anatomical coordinate system, which might have been different from the Virtual Corset coordinate system. Another aspect that might have contributed to the differences between the two devices was the maximum RMS error (1.4°) for the magnetic tracking device as a result of the simulated dental hygienist environment.

Visual inspection of the reaching-tasks graph for both devices demonstrates similar patterns. For the reaching task, there was a high correlation for the mean humeral elevation angle, demonstrating that the Virtual Corset pattern was similar to that of the magnetic tracking device. For the range of humeral elevation angles, the correlation was moderate; however, the change in the angles was very small relative to the magnitude of the range of motion.

The primary environment of the Virtual Corset is an occupational setting, in which it is measuring and identifying exposure parameters in the workplace during a workday, not specific angle at specific instance in time. For the flossing task, exposure parameters for humeral elevation were examined. The flossing task was performed for a longer duration (60 s) than the reaching task (3 s). During flossing, the dental hygienists had to floss between all the teeth, similar to the pattern they use during their workday. The jerk analysis found significant differences between the two devices. For both devices, the jerk analysis demonstrated that during flossing, the dental hygienists are more static or quasistatic than dynamic (more than 70% of the time). For the other exposure parameters (percentage time above a given angle), no interaction between the device and the position was found, meaning that any differences found between the devices were not related to upper-arm position. Main effects were presented for the device and position. In this study, the device main effect was of interest; no differences were found in percentage time above 20° of humeral elevations between the two devices. Significant differences were found for percentage time above 40° and 60°. However, the variability was large and differences between the means were small (8% and 3%, respectively).

The differences in exposure parameters between the two systems might be related to mean angle differences, although the predicted RMS error average for the flossing task was small (1.3°). High correlations were found for the percentage time above 20°, 40°, and 60°, which supports the hypothesis that the Virtual Corset has the ability to identify exposure parameters in the flossing task, as does as the magnetic tracking device.

In a study by Bernmark and Wiktorin (2002), they validated a triaxial accelerometer with in vivo conditions, static and dynamic, by using a 3-dimensional optoelectronic movement analysis system, Mac Reflex (Qualisys AB, Sweden). In the dynamic part of their study, participants performed arm pendulum (flexion and extension) at various velocities for 30 s and painted a specific area for the duration of 3 m. Their first dynamic task was similar to our reaching task, although we did not control for arm velocity. They did not report angle differences between the systems; however, when examining their graphs, we identified similar patterns of the differences between their two systems and ours. In the painting task, exposure parameter of percentage time above bins of 20° was used (from 0° to 180°). A small difference of 2% was identified by them. In our study, the differences were slightly higher, 3% to 8%. The reason for the differences could be related to their longer duration of data collection time, 3 min, whereas in our study, data collection duration for the flossing was, on average, 1 min.

Several limitations must be acknowledged. Only reaching and flossing tasks were used in this study, which might not necessarily represent a complete workday pattern for a dental hygienist. The duration of the two measured tasks were short as a result of a technical limitation of the magnetic tracking device and the collection duration of its interface software, Motion Monitor. The Virtual Corset was designed to collect data for a longer period of time, which might reduce the influence of outliers and as a result may reduce the angle error. In the current configuration, the Virtual Corset has 5 hr of data collection capacity, which is less than a typical full workday. An increase in the data logger memory size would extend the total data collection time. The use of the Virtual Corset in the field and data analysis would be easier with a start-and-end switch on the device. Currently, data collection starts and ends from the moment the battery is placed in or outside of the unit.

CONCLUSION

The Virtual Corset could identify similar kinematics patterns and exposure data when compared with a magnetic tracking device. On the basis of this analysis, we believe that the Virtual Corset can be used for data collection for dental hygienists and other professionals who have similar patterns of angular velocity and acceleration and humeral range of elevation as in dental hygienist flossing, for example, hairdressers. For occupations with higher angular velocities and acceleration, a prior use of the prediction equation is recommended.

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KEY POINTS

- During reaching and flossing tasks, the Virtual Corset can identify similar kinematics patterns and exposure data when compared with a magnetic tracking device.
- The results provide justification for the use of the Virtual Corset for data collection for dental hygienists and other professionals with similar patterns of angular velocity, acceleration, and humeral range of elevation.
- Because the Virtual Corset is a triaxial accelerometer, care needs to be taken in studying occupations with higher angular velocities and accelerations.

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