COMPARISON OF TWO METHODS OF MANUAL DIGITIZATION ON ACCURACY AND TIME OF COMPLETION

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The purpose of this study was to compare the accuracy and time efficacy of two methods of manual digitization (frame by frame, FXF and points over frame, POF). Two groups (experienced, N=20 and inexperience, N= 20) digitized markers using the FXF and POF method. The markers were digitized automatically using software HUMAN and the coordinates from the automatic digitizing were the true values and the manually digitized values were the measured values. These coordinates were used to compute an average root mean square (RMS) value for each subject. An ANOVA (Group x Method) was used to analyze the difference between digitizing time and RMS values. The POF method was more accurate than the FXF method in all of the landmarks analyzed. The advantage of the POF method lies in the ability of the subjects to continuously track the same point throughout the trial.

KEY WORDS: digitization, accuracy, errors.

INTRODUCTION: Errors during digitizing fall into two categories systematic and random. Random errors are introduced by the person digitizing the video and affect both the validity and reliability of the measurements. This error is often the result of improper alignment of the crosshairs over the landmarks or markers of interests. Systematic errors are associated with calibration errors, marker placement error and/or skin movement (Wilson, et al. 1999) or errors associated with the data collection procedures. Although automatic digitizing is readily available in most motion analyses software, in many instances it cannot be used in sports biomechanics. The use of external markers for the estimation of the joint centre is not possible in many sports biomechanics applications and even when external markers are used it is often necessary to digitize points manually. Most commercial motion analysis software's have the option of digitizing landmarks or markers frame by frame (FXF) or by tracking a single point throughout a trial, points over frame (POF). The FXF technique is a leftover technique from the film and analog-video days. Researchers preferred to digitize film or video frame by frame to avoid the repetitive rewinding of the fill or videotape which took more time and added wear and tear. With digital technology it is easier to rewind the video file without any damage video and therefore more efficient to track point using the POF technique. To the author's knowledge there is no research that has investigated the interaction between method of digitizing and the accuracy of the person digitizing. Our hypothesis was that the POF method of digitizing was more accurate and required less time than the FXF method.

METHOD:

Data Collection: A twenty-six frame two-dimensional video of a subject walking (60Hz) was used in the study. The walking video file contained a set of nine markers that were automatically tracked by a computer using the motion analysis software Human (HMA Technology, Ontario, Canada). The pixel coordinates of each digitized point were calculated and a scale factor was manually generated and applied to the all coordinates (automatic and manual). The 2D coordinates were then used to compare the digitizing methods. The two methods compared were manually tracking and digitizing each anatomical marker throughout each frame of the video (POF), and manually digitizing every anatomical marker on each frame (FXF).

Twenty experienced and twenty inexperienced subjects digitized the same trial using both digitizing methods. The order of digitizing method was randomized for both groups. Prior to the digitizing session the subjects were instructed on how to digitize and correct errors during process. The experienced group were students of an undergraduate biomechanics class that had been using the Human analysis software for a semester and had been instructed how to digitize with the software. Each subject digitized the trial with one method and after a brief rest of 10 min the same trial was digitized again with the other method. The time it took to complete each digitization process was recorded using a stopwatch by the investigator.

Data Analysis: Three markers (wrist, hip, and toe) were selected for the analysis. The wrist and toe makers were selected because their relatively fast motion during walking. The hip marker, although a slower moving point, it gets hidden behind the wrist marker during a portion of the trial and it is more difficult to track and digitized by the subjects. Joint markers were used since it has been shown (Bartlett, et al. 2005) that manual digitization of markers is more reliable than under a no-marker condition. The digitized coordinates were compared to the automatic digitized coordinates tracked by the computer. Automatic tracking was used as the benchmark for comparison, since previous studies have shown that it is more reliable (Bartlett, et al. 2005) and is equal or better in accuracy than manual digitization (Wilson, et al. 1999). The RMS between the automatic and the manually digitized resultant coordinates were computed frame by frame (N) an averaged for each trial.

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(auto - manual)^2}$$

The average RMS for each subject as well as the time taken to digitize the trial during the manual digitization methods were analyzed using a 2 x 2 mixed factorial ANOVA (group by method). This analysis was used to determine which method generated lower RMS values and was less time consuming. An alpha level of $p \leq .05$ was used in all the statistical analyses.

RESULTS: Figure 1a shows the average digitizing time between group and methods. There were significant differences between groups but not between methods. As expected the experienced subjects digitized the trial faster than the inexperienced subjects.

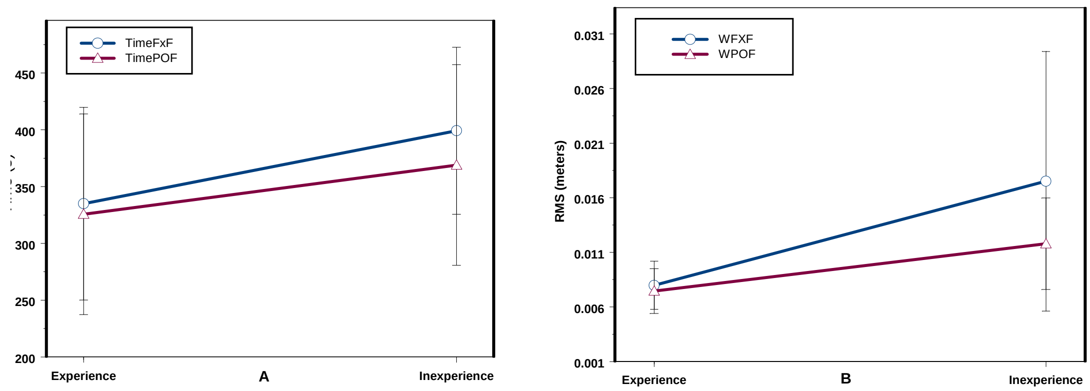

Figure 1. Mean and standard deviation values for (a) digitizing time and (b) RMS of the wrist markers

Figure 1b shows the average RMS for the wrist marker. Significant differences were found between group and methods, with a significant group by method interaction. The POF method had smaller RMS values, especially during the digitization by the inexperienced subjects.

The results of the RMS values for the hip and toe landmarks are presented in Figures 2a and 2b. Similar to the wrist landmark, there were significant differences in the hip RMS values between groups and methods, with a significant group by method interaction. Both groups had smaller RMS values with the POF method, with the inexperience group having an average RMS difference of 0.012 m when using the POF.

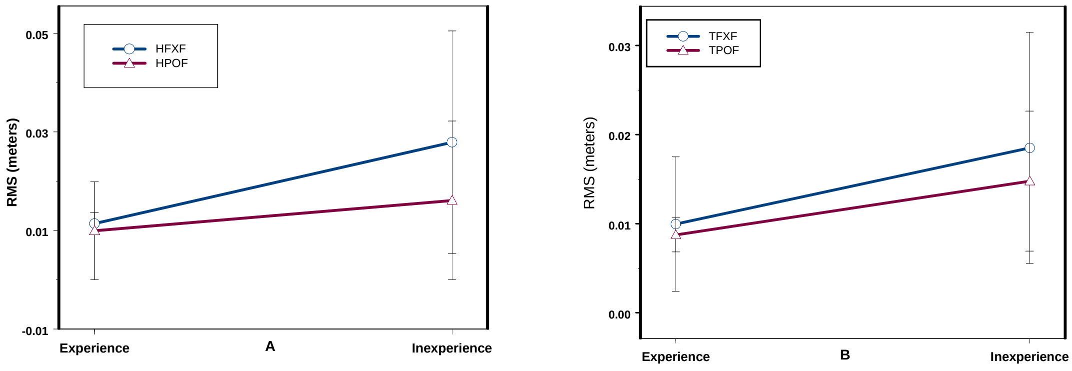

Figure 2. Mean and standard deviation of the RMS values for the (a) hip and (b) toe landmarks

Results for the RMS values for the toe landmark are presented Figure 2b. Although there were significant differences between groups, there were no differences between digitizing methods. The overall trend for the three selected landmarks showed that the POF method of digitizing produced lower RMS values than the FXF method and the RMS values were considerably smaller when the person digitizing lacked experience.

DISCUSSION: Human movement measurement contains errors due to the technological limitations of the motion analysis systems or errors associated with the person doing the analysis. Small measurement errors in the raw position data are then magnified in the calculation of the derivatives to obtain the velocity and acceleration data. Such errors are compounded about 20 times by the time acceleration is computed. It is imperative that these measurement errors are minimized by using better data collection and analysis techniques. Research studies have primarily focused on the validity and reliability of different motion analysis systems (Scholz 1989; Haggard and Wing 1990; Scholz and Millford 1993; Klein and DeHaven 1995; Richards 1999) or other systematic factors such skin markers (Schamhardt, van den Bogert et al. 1993), manual versus automatic digitization (Wilson, et al. 1999), size of the markers (Schamhardt, van den Bogert et al. 1993) and marker versus no markers conditions (Bartlett, et al. 2005) but, have not investigated how the method digitizing affects accuracy of the person doing the analysis.

Our research hypothesis was confirmed; the POF method of digitizing generated lower RMS values (less error) than the FXF method, and when the operator was inexperience the POF method of digitizing was more accurate than the FXF method. Although not significant, during the POF method both groups of subjects digitized the trial faster. Of the forty subjects that participated in the study, 31 of them preferred the POF method of digitizing because it allows them to track the marker better. The ability to track moving objects with the eyes is a highly complex task. It involves gathering information using several kind of eye movements such as smooth pursuit (continuous tracking of slow moving objects), saccadic (tracking of rapid movements), vestibulo-ocular (coordination of eye with head motion) and vergence (ability of the eyes to focus at various distance) (Knudson and Kluka 1997; Land and McLeod 2000). During POF digitization method, the subjects rely on smooth pursuit, fixation (careful focusing of both eye on an object), and saccade eye movements to track the marker from start to end. These eye movements are then used to predict the position of the next point accurately since the spatial information of the marker from the previous digitized frame is stored in short term memory. With the FXF method, the subjects rely on eye fixation because the information from the previous frame is not available as they digitize all the markers in one frame. It would be the equivalent to looking at the still image of point and trying to predict motion from that image. The visual information associated with the motion of the marker is lost since with the FXF digitization several markers are digitized in the same frame and it is not possible to maintain the spatial information of several points in short term memory. Even when the software predicts the next point, this information is often not accurate when points are moving fast or the change directions.

CONCLUSION: Manual digitization of the landmarks or markers should be performed using the POF method of digitization when available. Experience and inexperience subjects digitized markers with more accuracy and less time when using the POF method. The increased accuracy of the POF method would consequently reduce the amount of smoothing of the position-data.

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