9<sup>th</sup> Conference of the International Sports Engineering Association (ISEA)

# Monitoring stick speed and ball control in field hockey drills using a stick-mounted inertial accelerometer

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Elsevier use only: Received date here; revised date here; accepted date here

#### Abstract

Field hockey is a stick based sport where stick speed and ball control are primary skills. A stick mounted accelerometer was used to record hit events and the timing between them. The objective was to assess skill level using inter-hit timing in single-player drills. Eleven novice and nine state ranked male players performed three drills on artificial turf using both forehand and reverse stick hits at maximum stick speed. A 44 g stick-mounted 3-axis accelerometer was used to distinguish between forehand and reverse stick ball strikes and determine the time between ball strikes. Timing data and linear regression analysis was used compare the drills. The Chapman ball control test which requires no directional control recorded a shorter inter-hit time compared to other drills where the ball direction was prescribed. Reverse-stick drills take the longest time for effective ball disposal. Reverse stick drills requiring control of the ball direction are not commonly part of skills training and the speed of ball delivery is much lower when compared to similar forehand drills. The Modified Chapman ball control test results showed the highest correlation to hockey performance levels.

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Keywords: field hockey; skills monitoring, inertial sensors, Chapman ball control;

### 1. Introduction

In the last twenty five years, field hockey has been subjected to scientific analysis in a number of different ways including physiology [1, 2], blood chemical analysis [3], and perception [4]. In addition, a number of papers have reported techniques to assess the physical performance capabilities of field hockey players [5]. All of these techniques relate to physical fitness and the ability of athletes to play the game at near maximum performance levels and with a good understanding of the game.

\*Corresponding author. Tel: +617 37357192; fax: +671 37355198 E-mail address: d.thiel@griffith.edu.au Measures of skill level require a different testing regime. Commonly the skill level of sub-elite athletes are assessed by coaches without instrumentation. There are many field hockey drills used during training sessions [6, 7] but often no quantitative measure is made. The game requires the skills of ball control, stick speed, hitting power and dribbling speed. A field hockey skill test, the Chapman ball control test [8, 9], was validated using elite players. Two other drills have also been validated as measures of skill [9]. In these tests no measurement instrumentation was used apart from a stop-watch.

At the elite level, stick speed and ball movement can exceed the capacity of a human observer to measure. For example, in the Chapman ball control test, an observer is asked to count ball hits at a rate of more than 5 hits per second for 15 seconds. This measurement is conducted with one player, one timer and one scorer-recorder [8]. This paper reports a new accelerometer-based method to gain accurate data in which the measurement error is reduced and the drill can be conducted without supervision.

## 2. Methods

#### 2.1. Accelerometer measurements

Microelectromechancial machined (MEMs) accelerometers are small and light weight, and widely available [10]. Measurements reported here used an accelerometer unit (n-core) which has a 6g, triaxial accelerometer with 100 samples/s acquisition data logging [11]. The device has been used in swimming, running and other sports as a human mounted movement sensor [12, 13]. These small devices have little effect on the aerodynamics, weight and balance of many racquet/bat/sword/club based sports. Accelerometers have been used on cricket bats [14] and martial arts swords [10].

A hockey stick has length 927 mm and weight of 500-600 grams. The n-core unit consists of a circuit board (55 mm x 29 mm x 6 mm, 7 grams) and a battery pack of two AAA (61 mm x 25 mm x 15 mm, 37 grams). Attaching the accelerometer to a hockey stick increases the weight by 7%. The n-core was taped to the right side of a hockey stick at approximately 100 mm above the bottom to minimise interference to the player's lower hand. Commonly a ball hit is registered on the accelerometer for approximately 0.02 seconds which means that every strike is recorded but the magnitude of the deceleration of the stick can not be accurately determined. Forehand ball impacts can be readily distinguished from reverse stick impacts in the accelerometer record.

#### 2.2. Hockey Drills

The two groups tested were members of the Queensland State Men's hockey (9 players with various experience - national squad, state squad and state junior ranks) and fit males who had little (3 social players) or no hockey experience (8 novice players). Ethics approval was obtained prior to commencement (ENG/08/09/HREC). All drills were conducted on a synthetic hockey playing surface. Players used their own hockey stick. The drills were designed for one player to remove the variability associated with the performance of other players. One drill required the presence of a second person to roll the ball. The other drills can be undertaken without supervision as the ball is initially stationary. In this study, all activities were supervised during data gathering. The three hockey drills used are outlined.

# 2.2.1. Modified Chapman ball control test (i.e. ball movement in the control box):

The Chapman test requires the player to move the ball around the control box (i.e an area approximately one stick reach from the centre of axis of the player). The ball must travel a distance of more than one circumference between hits. The number of hits was counted over a 15 second period. The

direction of the ball is unimportant. While the usefulness of this drill as a measure of player ability has been questioned [15], results have correlated well with player performance levels [8]. Elite players achieve Chapman scores of up to 78.41 (SD = 18.16) which is equivalent to approximately 5 hits per second. This approaches the limit of human observation. In our test, the median number of hits per second was determined from a 15-30 second record [16]. The median value  $t_{median}$ , eliminates double hit strikes, unregistered hits and lapses in ball control. The modified Chapman score is  $15/t_{median}$ .

#### 2.2.2. Two hits and a flick (FH3 and RS3)

The player faces the goal with a stationary ball placed on their preferred side (approximately 20 cm in front of the right foot). The player moves the ball left to right and back (2 hits) and then flicks the ball at the goal (see Figure 1 left). The flick was used to minimise the time between the hits as less back swing is required. The time between the first and last hit was recorded (FH3). Three attempts were made and the shortest time derived from the accelerometer record. The exercise was repeated in reverse with the ball start position on the non-preferred side (RS3).



Figure 1: Left: Two hit and flick ball movement. (a) FH3 and (b) RS3. The time is measured between hit 1 and hit 3. Right: Trap and hit drill ball movement (a) TFF and (b) TTFR. The time was measured between hits 1 and 2.

## 2.2.3. Trap and flick (TFF and TFR)

The ball was rolled in front of the player from a distance of approximately 3 m. The player was required to trap the ball with one hit and flick forward (TFF) (see Figure 1 right). The time between the stop and flick was measured. The reverse trap and flick (TFR) required the player to trap the ball on the non-preferred side and reverse-stick flick forward.

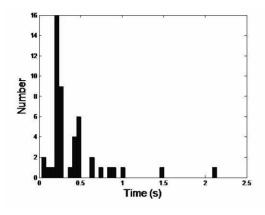
## 3. Results

The three axis accelerometer data was combined by calculating the vector sum of the three components. Ball strikes were identifiable on the record and recorded at the time of maximum positive slope. Multiple ball strikes during the same "hit" were eliminated using a 0.05 s gap between consecutive counts.

Figure 3 (left) shows a histogram of the inter-hit times for one player. The median value was 0.25 s. The second peak at 5 s (twice the median value) suggests that some hits were not identified. Figure 3 (right) shows the results of the modified Chapman test. The results reported by Chapman [8] are plotted as a mean and standard deviation for three categories of players (Olympic team, Olympic squad but not team, Olympic hopefuls but not squad). Figure 3 indicates a strong trend between the modified Chapman test and player ranking. The mean and SD for novice players was  $34.4 \pm 7.6$  and for the State squad was  $66.3 \pm 9.3$ . This difference is statistically significant (p<0.01). The State squad data is comparable with the original Chapman data [8] despite the significant differences.

The shortest time (FH3 and RS3) from three attempts was recorded for forward and reverse-stick drills. The group mean, SD and lowest times are listed in Table 1. FH3 values are slightly less than the RS3 values, however 35% of the players scored less for the reverse stick drill. The FH3 and RS3 values

are not statistically distinct within each group but differ between the groups (p<0.01). TFF values are less than TFR values and no players scored an individual TFR < TFF. The mean values are statistically distinct both in the group and between the two groups (p<0.01).



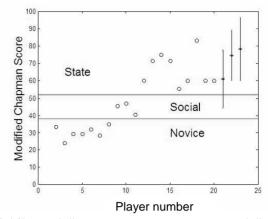


Figure 3: Left: Typical histogram for the inter-hit times for the modified Chapman ball control test. Right: Modified Chapman ball control test results ranked by player experience. Data points (\*) with SD error bars show the results reported by Chapman [8] for elite and sub-elite players.

Table 1: Mean, SD and best time values for FH3, RS3, TFF and TFR.

	FH3 (s)	RS3 (s)	TFF (s)	TFR (s)
Novice & Social	1.35 <u>+</u> 0.22	1.50 <u>+</u> 0.31	0.63 <u>+</u> 0.13	0.94 <u>+</u> 0.15
State	0.70 <u>+</u> 0.11	0.68 <u>+</u> 0.14	0.38 <u>+</u> 0.06	0.56 <u>+</u> 0.10
Best Score	0.55	0.54	0.25	0.41

The best inter-hit time data was compared for all drills and all players. The objective was to assess the difference between the Chapman and the other drills where the direction of each hit was prescribed. The inter-hit time from the modified Chapman test was compared to FH3/2 and RS3/2, and TFF and TFR times. The results are plotted in figure 4 and Table 2 lists the slope, intercept and the linear (Pearson) correlation coefficient R<sup>2</sup>. For all but the TTF time, the slope was greater than unity indicating that the inter-hit times are greater than the Chapman times. This is an expected result as the player was required to control the ball direction. RS3 has the largest slope indicating that this is the most difficult drill for most players.

The lowest slope (0.79), TFF indicates that players are most comfortable trapping and flicking the ball on their forehand side. This is a common ball control drill used during practice to improve goal shooting. FH3 yielded the inter-hit times closest to the modified Chapman test (slope 1.07) however, the correlation is not strong ( $R^2 = 0.58$ ). The correlation coefficients for TFF and TFR were quite low indicating considerable player variability when compared to Chapman scores.

#### 4. Discussion

The Chapman ball control test [8], while well known in hockey skills assessment, has been dismissed as not engaging players in hockey "playing ability" [15]. For this reason 3 hit and 2 hit drills were

measured for comparison. Given that during a match, players spend very little time with the ball under their control, the additional tests involved prescribed ball movement with the direction of the ball changed through 90 degrees. The time between the first and last hit was recorded and the inter-hit time calculated. This proved to be a statistically different measure of stick speed and ball control. In most hockey games, particularly when the ball is within shooting range of the goal, the speed of ball control and delivery should be as small as possible. The shortest time between hits was 0.18 seconds recorded for the forehand trap and flick drill. Measurements of this duration can only be made reliably using electronics or high speed video. A 15 second interval is a very long time for a hockey player to have the ball in his/her possession and some concentration is lost. The use of the median score in the modified Chapman test reduced this factor to some extent.

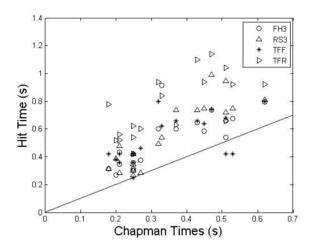


Figure 4: Scatter plot showing the best drill scores hit times (normalised to the number of hit intervals) for all drills compared to the modified Chapman ball control test timing. The line has a slope of unity.

The shortest time between hits was observed in the forehand trap and flick drill commonly practiced at training. All players found reverse stick drills more difficult. The use of these drills in training and player assessment may improve match play. This would require a longitudinal study of player development.

The set of three drills took players less than 6 minutes to complete (includes attaching the n-core and return the unit). The measurement team consisted of three people supervising the three drills, and two people handling the n-core units and the software analysis. The software application provides feedback to the player before returning to training. The disruption to normal hockey training was minimal.

#### 5. Conclusions

Field measurements of stick speed, stick rotation and the time between ball hits in training drills were undertaken using a three axis accelerometer taped to the right side of the hockey stick. Forehand and reverse stick ball strikes are clearly evident and were used to determine the time between hits in three hockey drills. Timing results for novice (n = 11) and the state level players (n = 9) showed significant differences in a modified Chapman ball control test, a three hit drill and a trap and flick drill. The best elite player achieved a Chapman number of 83 and an inter-hit time of 0.18 s. The weak correlation

between the modified Chapman data and the trap and flick data indicates these drills require a different skill level. This low cost measurement technique allows coaches to monitor youth training and skills improvement in field based exercises without the use of expensive video.

Table 2: Linear correlation data for all drills compared to the Chapman time.

Drill Type	Slope	Intercept	$\mathbb{R}^2$
FH3	1.07	0.146	0.5844
RS3	1.56	0.013	0.7756
TFF	0.79	0.245	0.3929
TFR	1.17	0.343	0.4945

#### Acknowledgements

The authors appreciate the cooperation of the Queensland Academy of Sport (Peter Shaw and Barry Dancer), the Centre of Excellence in Applied Sports Science Research (Sue Hooper) and the Queensland Men's State Hockey squad (coach Matt Wells). Ethics approval ENG/08/09/HREC.

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