FINGER AND THUMB FORCES DURING BOWLING SHOTS

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The purpose of this study was to measure the forces exerted to a bowling ball by thumb and fingers during two different shots. For this task, an instrumented bowling ball was designed and produced, which allowed for force measurement and display of vector diagrams. The highest force is applied by the thumb (up to 120N), followed by middle and the ring finger. The overall moment applied to the ball by thumb and fingers during twisting of the ball reaches 3 Nm.

KEY WORDS: finger forces, bowling, bowling ball, instrumentation, force transducers.

INTRODUCTION: In the 1930's, British Anthropologist Sir Flinders Petrie became the first to discover evidence of a bowling-like game. He found ancient objects in a child's grave in Egypt that were allegedly used for a primitive form of the game. These artifacts have been dated back to 3200 BC, effectively making bowling over 5,000 years old. The first written mention of a bowling-like sport can be traced to the year 1366 in England. Allegedly King Edward III outlawed the game in order to keep his troops focused on their archery practice, but it was most certainly in vogue during the reign of King Henry VIII.

The vast variety of commercially available bowling balls fall into three general types of balls:
1. Polyester balls, typically used by beginners, are usually used in a "straight shot". This is because the polyester surface creates very little friction with the lane, causing it to slide more.
2. Urethane balls are made from polyurethane, a form of plastic, which generates a varying amount of friction with the lane, depending on the ball. These balls are used by people who like to throw a hook or spin shot (sometimes known as the helicopter shot).
3. Reactive resin is the last of the three types of balls. This material is relatively new, with designs still evolving. Reactive resin balls are typically used in hook or spin shots. However, these balls seemingly explode upon hitting the rack, which makes them favorites among more experienced bowlers.
There are several types of shots in bowling, all of which can be very effective. All shots fall into three main categories defined by their actions:
1. The "straight ball" is used mostly by beginners and is done simply by throwing the ball in a straight line down the lane.
2. A "hook ball" is throwing the ball in a manner in which it moves in a smooth arcing motion down the lane. This allows the ball to enter the pocket at an angle, which helps to create more "pin action."
3. A "spin shot" is such that the ball is released to create spin on its vertical axis. The bowler attempts to utilize the deflection of the bowling ball off the head pin, subsequently, running the ball down the side of the deck so that the spin mixes up the pins to carry the strike.
There are two basic grips in bowling:
1. The "conventional grip" is the standard grip typically seen in a "house ball" (a ball provided by the bowling center). This type of drilling allows the middle and ring finger to slide into the ball down to the second joint or knuckle, and the thumb to enter a third hole below. This enables the bowler to have a firm grasp of the ball. Because it is easier to control, the conventional grip is used by beginners throwing a straight shot. This grip also allows the bowler to do a hook shot or a spin shot as well.
2. The "fingertip grip" is a relatively different type of grip, typically used by more experienced bowlers looking to throw a hook shot. As the release of the ball with a hook is very different than that of a straight ball, the fingertip grip is used to facilitate the slipping of the fingers from

the bowling ball. It is drilled to a depth such that the middle and ring fingers can be inserted up to the first knuckle only.
Literature sources on bowling concentrate on theoretical calculation of ball parameters and motion (Hopkins and Patterson, 1977; Falcioni, 1993; Frohlich, 2004). However, forces applied by the fingers to the ball during the approach have never been measured.
The aim of the study was to produce an instrumented bowling ball, and to measure the finger forces during two different types of shot; conventional hook and conventional spin.

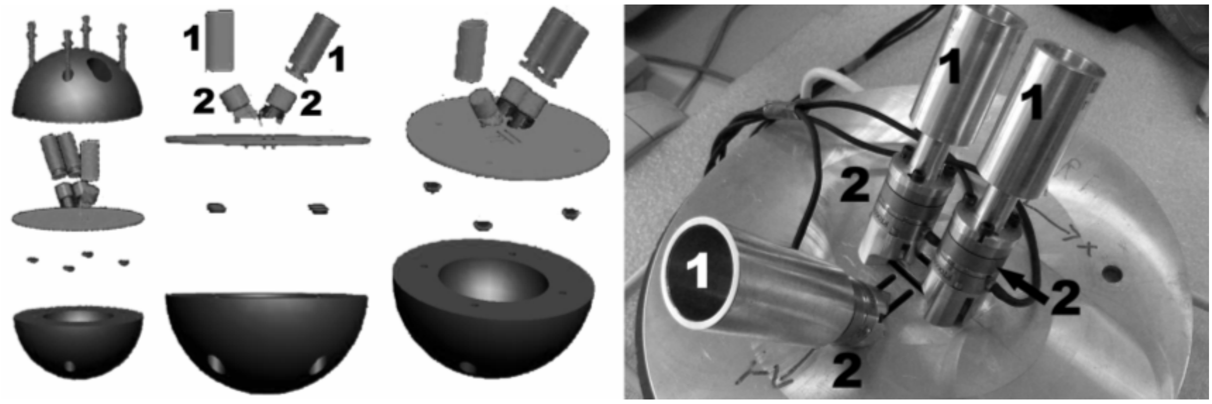

Figure 1: Design and components of the instrumented bowling ball; 1 = metal tubes replacing the finger and thumb holes, 2 = force transducers

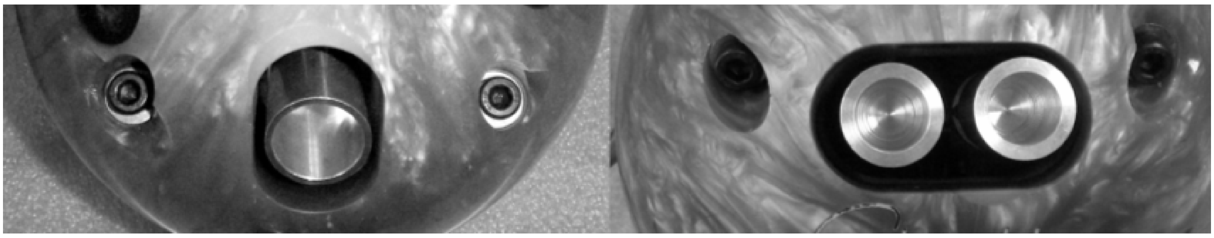

Figure 2: Thumb and finger holes

METHOD:

Equipment: For this study, an instrumented bowling ball was developed (Fig. 1), equipped with three 6-DOF silicon strain-gauge force sensors (Nano25, ATI Industrial Automation, Apex, NC, USA). In a commercially available bowling ball (Columbia 300 Blue Dot), the finger and thumb holes (Fig. 2) were replaced by aluminium tubes, connected to the transducers (Fig. 1).
Data Collection: The force and moment data was recorded at 1 kHz and collected with LabView (National Instruments, USA). Additionally, the right shoulder and elbow joint were equipped with electrogoniometers (EGM, Biometrics, USA) to assess the swing kinematics at 1 kHz and to connect the force data to the angular displacement of the joints. A force switch, connected to the EGM data logger and glued to the thumb tube, provided the trigger signal between force transducers and EGMs.
The experiments were carried out by a subject (E.C.H.K), who is a recreational bowler. Two different types of shot, the hook and the spin, were applied 5 times each. Due to the cables connected to the ball and the transducers, the ball could roll only for a few centimetres before it was stopped; yet, once the ball was released, the forces applied by the fingers to the ball are non-existent. Hence it was not essential for the ball to roll the entire lane.
Data Analysis: The forces were analysed as to 3 components (x, y, z) with respect to time, resultant finger force with respect to time, and overall force applied to the ball. From the moment equilibrium, we calculated the origin (centre of pressure, COP) of the resultant finger force at the inner surface of the tube. Additionally, we computed the overall ball moment produced by fingers and thumb about an axis perpendicular to the frame plate of the transducers. This served to quantify the twisting moment for spin effects. Finally, the vector

diagram was generated and visualised in AutoCAD 2000 (Autodesk, USA) by combining COP and resultant force, whereby force vectors applied by the ball to fingers and thumb, were displayed on the ball (comparable to Pedotti diagrams in gait analysis).

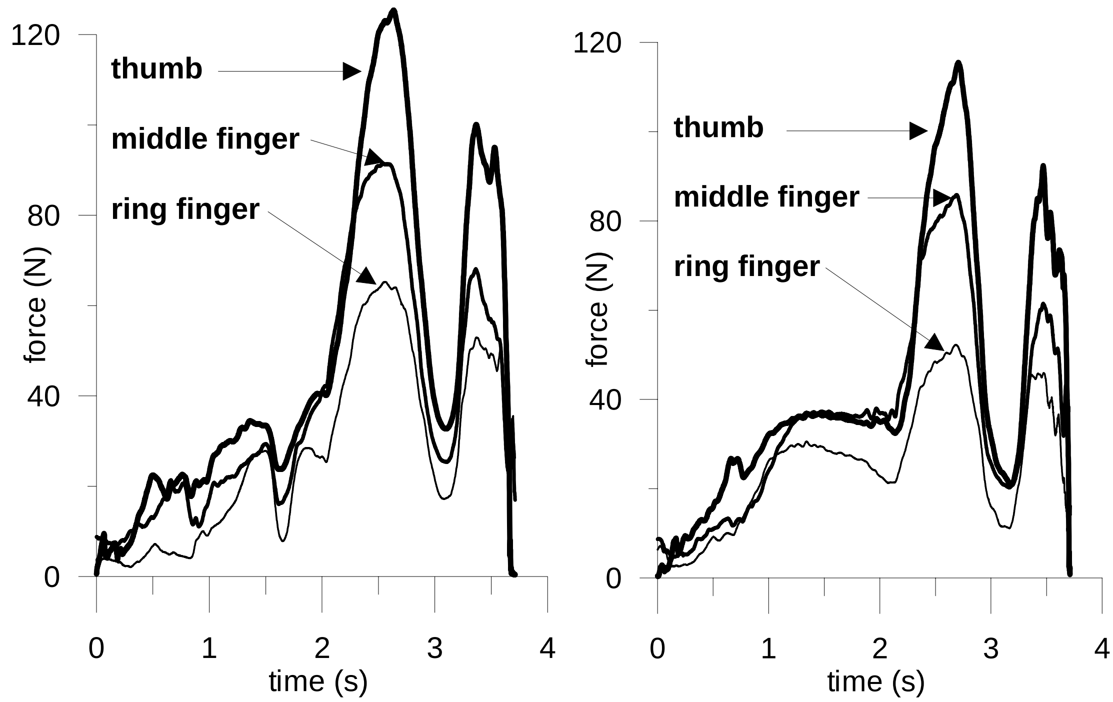

Figure 3: Finger forces (resultant) without (left side) and with (right side) twist

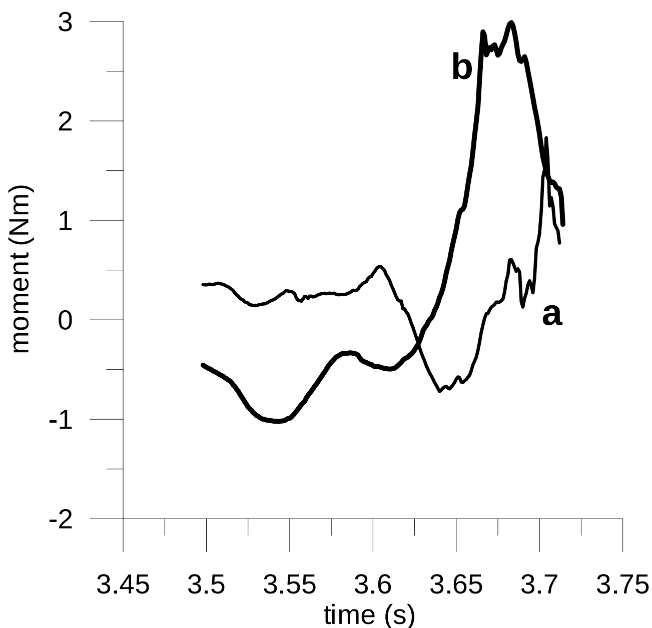

Figure 4: Moment applied to the ball during the 2nd half of the forward swing; a = without twist, b = with twist

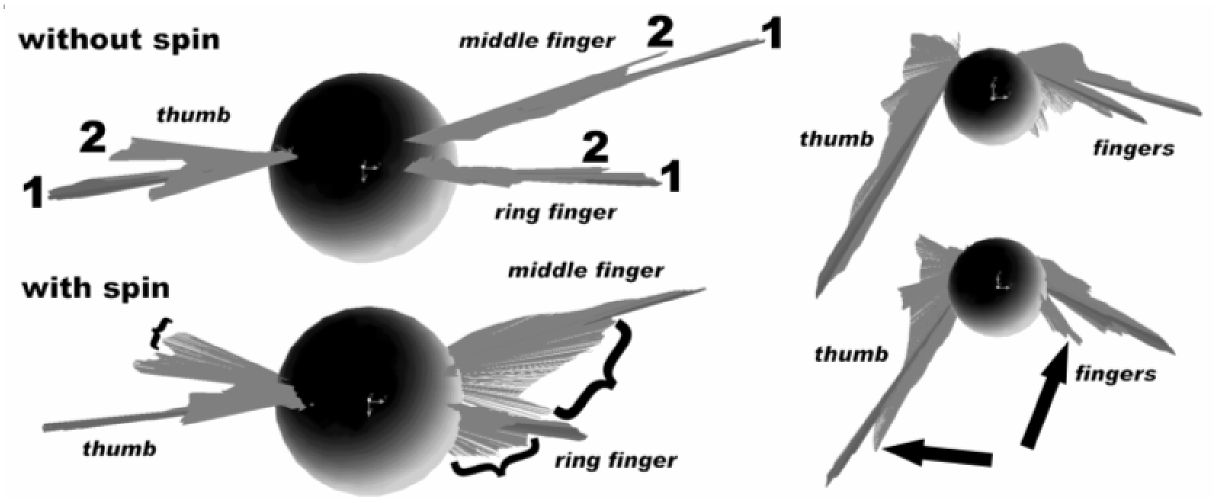

Figure 5: Vector diagrams without and with spin. 1: force spike during back swing, 2: force spike during forward swing; the curly parentheses indicate the additional forces during twisting just before release of the ball.

RESULTS and DISCUSSION: The highest force is applied by the thumb (124±9N), followed by the middle finger (92±7N) and the ring finger (63±8N; Fig. 3). The force-time diagram shows two spikes (Fig. 3), which are related to back and forward swing of the shot. The overall moment applied to the ball by thumb and fingers reveals the twisting effect (Fig. 4), which occurs 50-100 ms before release of the ball. Both force spikes and additional twisting forces are also visible on the vector diagrams (Fig. 5).

The instrumented bowling ball presented in this study allows for accurate measurement of thumb and finger forces. As expected, the thumb exerts the highest force. Additionally, the spin moment of the ball (up to 3 Nm) can be quantified. We are currently investigating modifications of the instrumented bowling ball, specifically hook balls with shorter finger tubes.

CONCLUSION: The application of the instrumented bowling ball extends to measurement of approach consistency and training level control. It is intended that a wireless version of the instrumented bowling ball is produced so as to compare the ball dynamics during the shot to the ball kinematics on the lane.

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