RESEARCH

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A Biomechanical Approach of the Life Preserver Throwing in Lifesaving: Case Study

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The purpose of this study was to use the discus throwing technique for throwing a life preserver, in order to identify the required biomechanical parameters of the throwing technique for saving a human life. Video recordings of simulated rescues with a life preserver from an elite male lifesaver (n=1), with a speed of 25 frames/sec were analyzed in the Software Wdigit. The direct linear transformation procedure was used to obtain 2-D data from these records. Results show that speed of release of 5.95m/s, angle of horizontal distance of 36.5^o, height of release of 2.04m are enough for achieving a rescue 10m far from safety with a life preserver when the rescuer is 1.88m tall.

Key words*:* lifesaving; lifeguarding; rescue

Biomechanics as a scientific activity is not new. Already in its practice were Aristotle and Leonardo da Vinci (Huiskes et al., 1982). One of its major objectives is the development of methods for the optimization of human motions (Hatze, 1976). Modern coaches utilize apart of all and biomechanical means to optimize athletic performance in various events. Biomechanical methods quantify the output of performance so that coaches and athletes are assisted by movement analysis (Ariel, 1980). Nevertheless, a little attention has been paid to the life saving approach of biomechanics. Only one study has been reported in calculating biomechanical parameters in that particular field (e.g. Daniel & Klauck, 1992). On the other hand, several scientists have explored from their biomechanical point of view, the event of discus throwing (Knowles, 1999; Roscoe, 1999; Tidow, 1994). The element of throwing a life preserver in order to save a human life hasn't still been researched. Even in the popular water-polo, only few studies have analyzed the biomechanics of throwing techniques (Clarys, Cabri, & Teirlinck, 1992). The purpose of this study was that even if no further insights into discus technique can be gained from kinematic analyses (Knicker, 1994), the use and transformation those characteristics of the technique used by a discus thrower that are most closely related to the throwing of a life preserver, could serve as a basis for identifying an ideal throwing technique for saving a human life. The traditional acceptable kinematic data of discus throwing were used in the present study, in order to provide a better understanding for the life preserver throwing demonstrated by a qualified lifesaver.

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A several number of different lifesaving techniques, provide a great tool selection for a potential lifesaving attempt. On the other hand, all these available techniques, are selected based on the different characteristics of the casualty (weak, non-swimmer, injured, unconscious) and also of the distance which is needed to be covered in order the casualty to approach the rescue aid provided by the lifesaver (rope, live preserver, personal flotation device etc.). A lifesaver usually follows the internationally standardized order of reach, throw, wade, row, swim with aid, and tow for saving a drowning casualty (Eaton, 1995; Elkington & Holmyard, 1967; Sims, 1997; Singapore Life Saving Association, 1990). The throw technique is very useful, as it allows a non-contact rescue and guarantees safety for the lifesaver. In the present study, it was supposed that the casualty is cooperative in a distance of 10m, where the throw technique of a life preserver, is a potential decision for action. It was tried to use all the known information about the discus throw, which seem to be closed related to that of life preserver's one.

The skill of throwing is probably second only to running as a common element in a wide range of sports (Bunn, 1972). The purpose is to project an object so that it has a flight phase. In a throw, the object is supported by a limb, usually the hand, and displayed through a range of motion while the limb increases the quantity of motion, *or momentum*, of the object. Typically several body segments, in a proximal-to-distal sequence, contribute to the object's momentum (Putnam, 1993). As distinguished from the more simultaneous arm actions in a push, throwing involves the sequential action of body segments progressing from the larger, slower-moving trunk actions to the faster, distal actions of the relatively smaller arm and hand segments. Depending upon the demands of the sport, both speed and accuracy in varying combinations constitute the goals of a throw (Atwater, 1979). Although the throw can be characterized by the progressive contribution of the segments to the momentum of the object to be projected (with a constant mass, of the change in momentum corresponds to the change in velocity), the task can be accomplished with a variety of motions. These differences in form include the over-arm throw (e.g. baseball, cricket, javelin, darts), the underarm throw (e.g. soft ball pitch), the push throw (e.g. shot put), and the pull throw (e.g. discus) (Enoka, 1994). Kinematic variables are involved in the description of the movement, independent of forces that cause that movement (Winter, 1990). The kinematics of the throwing motion are typically 3-dimentional in nature, especially when the throw is for maximum distance (Feltner, 1989; Feltner & Dapena, 1989; Feltner & Dapena, 1986).

If a biomechanical parameter exhibits a strong linear relationship with the criterion, and if a logical cause-effect relation exists, it would seem reasonable to suggest that improvements in performance could be sought via improvements in this parameter, regardless of the performer's present level of achievement (Hay, Wilson, & Dapena, 1976). For that reason, there have been referred the basic contributors that influence on the discus throwing in order to be used by lifesavers, during a life-preserver throw. In sport events that incorporate flight, several factors influence the character of the flight path (Carr, 1997).

Height of release

Some athletes are taller than others so their body type can increase the height of release (Carr, 1997). Also the horizontal distance increases with increases in the height of release (Kreighbaum & Barthels, 1990). The average height of release among elite athletes is about 1.90-2.10m (Georgiades, 1991).

Speed of release

Given the same height and upward angle of projection, the object with the greatest velocity will go farther. The horizontal distance increases with increases in the velocity (Kreighbaum & Barthels, 1990). The speed of release is the most influential determinant of the distance of the throw (Hay & Yu, 1995; Kreighbaum & Barthels, 1990). Also that, in most cases, the aerodynamic forces exerted on the discus during the flight increase the distance of the throw (Hay & Yu, 1995). The literature doesn't refer the speed of release of a discus throw. Nevertheless elite javelin athletes, have normally a speed of 5.5-7.6m/s (Georgiades, 1991), which make as to believe that the throw of discus would be similar.

Angle of horizontal distance

With a given release height and speed, there is a unique projection angle that results in the object's traveling the greatest horizontal distance compared to that achieved at all other angles. The horizontal distance increases with increases in the height of release, but the ideal angle decreases as the height of release increases. Thus, the taller the thrower, the less of an angle needed to produce the greatest distance for a given speed of release (Kreighbaum & Barthels, 1990). This angle is usually between 30^o-40^o when the throw is performed by elite athletes (Georgiades, 1991).

Angle of attack

The discus is relatively unstable in flight, so the angle of attack a release must be small enough to prevent early stalling, which forms an angle of attack between 26-29^o (Ganslen,1964).

Height of performer

Throwing an object for distance involves projecting the object from a height. The height of the CG of the object depends on the height of the performer and on the place where the performer releases the object relative to the ground (e.g. underarm, overarm, and sidearm). Therefore, a tall performer has an automatic advantage over a shorter performer throwing with the same projection velocity (Kreighbaum & Barthels, 1990). The height of Olympic athletes of discus is usually estimated 1.88m (Carter, 1984).

Muscular strength

A discus thrower must combine the physical attributes of height and weight with the physical quality of strength (Tancred & Carter, 1980). Special strength training has become an important part of training in the throwing events (Losch & Boettcher, 1994). Nevertheless, the importance of the muscular strength, as an important variable in discus throwing is not well researched and so, this debate will continue.

Gender

Darden (1979) stated that the reason women throw more poorly than men is that 'a woman's forearms are connected to her upper arms at a different angle from a man's'. However, in a radiographic study of both sexes ranging from infant to adult, Beals (1976) found no significant differences between males and females in the normal carrying angle of the elbow. Thus, other factors such as strength differences should be examined to explain why the average female does not usually achieve as high a throwing velocity as the average male (Atwater, 1979).

Shape of object

The form or shape of the object, determines how smoothly the object can cut through the fluid. Objects that are streamlined in shape are those that tend to create a streamlined flow pattern so that turbulent flow is minimized and laminar flow is sought to be maintained (Kreighbaum & Barthels, 1990).

Position of object

The shape alone has no advantage in reducing drag unless that shape is positioned properly relative to the air flow (Kreighbaum & Barthels, 1990). The discus is very much affected by the way the wind is blowing. Head winds approaching from a favorable angle and blowing at an optimal velocity (about 15-20 mph) can dramatically increase the distance that the athlete throws. With a head wind the thrower reduces not only the angle of release, but also lowers the leading edge of the discus. If the discus is tilted up too much is stalls in flight and the distance is dramatically reduced (Carr, 1997).

Relatively recently mathematical modeling of the human body in conjunction with high-speed cinematography has provided a fruitful approach to the quantitative assessment of movement patterns (Zernicke & Roberts, 1976). Nevertheless, the techniques used in the discus throw (and in the other throwing events) have only rarely been the subject of biomechanical analysis. The main reason appears to have been that these techniques are 3-dimensional in nature and are thus not readily analyzed using the 2-dimensional approach so frequently used in analyzes of the other events in track and field (Hay & Yu, 1995).

Method

Subjects

An elite male qualified lifesaver from the Royal Life Saving Society UK and the European Lifeguard Academy at distinction level (age: 26-yrs, height: 1.88m) was used as subject.

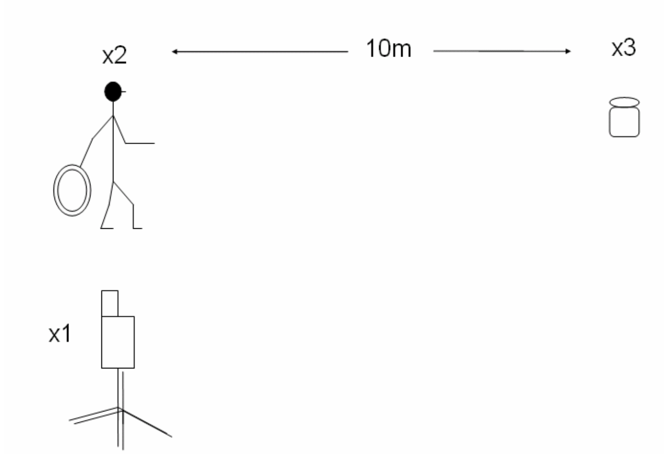
Instruments

A Canon XLDM1 video camera was used to record the performances of the subject, with a speed of 25 frames/sec; the direct linear transformation procedure was used to obtain two-dimensional data from these records. Although the kinematics of the throwing motion are typically 3-dimentional in nature, especially when the throw is for maximum distance, in the present study the distance was only 10m and so a 2-D analysis was used. The video camera was placed on the tripod 'Model #132 Manfrotto professional tripod (Italy)'. The lights which used were the 'Highlight Photon Beart UK' and the 'Model 5574 500 Watt x 2, 230V~ AC (500Watt x 2)'. The motion was recorded using a TDK video cassette of 120min in the video recorder 'AG-MD 830 Panasonic'. The findings then were downloaded in a Zip™ Iomega disk of 100MB and were analyzed in the Software Wdigit. A 'Peray DOT (UK) Approved' life preserver, (diameter =52cm, width = 7cm, weight =1.30kg, 24'' Perry Buoy, Pat No 982601 and Foreign Pats Pending), was used as object of throw.

Procedures

The simulated rescue, occurred in the long corridor (height=2.96m, width =1.96m) of the Biomechanics laboratory of Leeds Metropolitan University in England. The casualty was simulated by an object (height=26cm, diameter=33cm), 10m far from the thrower (lifesaver). The purpose was that the object should have approximately the same size with the only visible part of a casualty's body; the head. The thrower was standing at the force platform. Marks were placed on the skin of the subject to define the joints of the shoulder, wrist, knuckle, hip, knee and angle. The video camera was in 90^{o} angle with the lifesaver's body, from the side of his right hand, which demonstrated the release (figure 1). Fifty attempts were recorded and used for further analysis in the computer. The video was then downloaded in the computer. Using the Draw program, it was analyzed a variety of different findings, related to the life preserver throwing. The number of the frames was 30 with a sampling rate (constant) of 25.0Hz. The Butterworth cutoff frequency range was 1.0 to 6.7 Hz. There was not chosen any filtering and Linear spline order as well.

Figure 1: Graphical representation of a simulated rescue in the corridor of the lab, of a casualty by a qualified lifesaver using the life preserver throwing technique.



Note. X1: Video camera's, X2: Lifesaver's, position of release, X3: Casualty's position simulated by a bin, a: Distance between simulated lifesaver's and casualty's positions.

The throwing was not affected by the wind, because the environment was indoor and there wasn't any chance of wind blowing. Because 'angle of attack' is called the negative angle of attack between the direction of the wind (relative wind) and the flat face of the discus (or the life preserver) (Georgiades, 1991), in that throwing there wasn't present and therefore it wasn't estimated.

Results

The height of performer was measured to be 1.88m. The height of release for the subject was calculated using the toe's coordinates (x_1= 2.39, y_1= 0.36) and also the right knuckle's (x_2= 3.42, y_2= 2.40) during the release (20th frame). The equation which was used, was d= d_2-d_1 where, d= distance, x= x_2- x_1= 3.42- 2.39= 1.03m, and y= y_2-y_1= 2.40- 0.36= 2.04m.That permitted to find the height of release which took place from the point x=1.03m, y=2.04m.

The release occurred during the 20th frame. The body joint which represented the throw was the right knuckle. During the 20th frame, the linear velocity of release of the right knuckle was for the x= 4.75 and for the y= -3.5875. Based on Pythagora's equation (figure 2), the resultant velocity which represented the speed of release, was Resultant $_{(velocity)}{}^2$ = x $_{(velocity)}{}^2$ + y $_{(velocity)}{}^2$ or $R^2_{(v)}$= 4.75^2 + $(-3.5875)^2$= 5.95m/sec. Consequently the speed of release is 5.95m/sec. Using Pythagora's equation, it was found the angle of horizontal distance to be 36.5^o (see figure 3).

Figure 2: The speed of release of the life preserver is represented by the Resultant velocity of the x and y coordinates, of the right knuckle at the 20th frame.

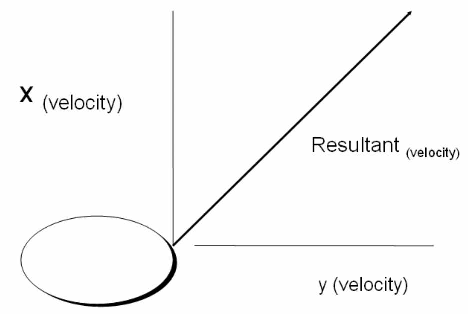
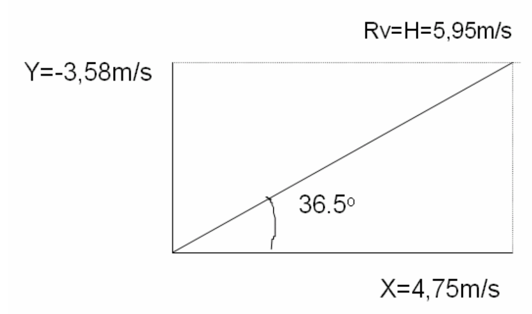


Figure 3: The angle of horizontal distance of the life preserver throw was estimated with Pythagora's equation.



Discussion

As far as it is known this is the first report of a life preserver throwing by a qualified lifesaver, which approaches the phenomenon from biomechanical point of view. The current findings are subject to a number of limitations. Firstly, the available literature on that field, did not allow relating the present findings with other already existed. Also, the fact that this research was a case study it doesn't permit integration of the conclusions. Computer calculations are likely to include errors on the height of release, because the life preserver during the 20th frame (when the release occurred) covered the joints of the right knuckle and hand during the video recording and so the digitizing of the joints and the body segments was approximate and possibly not always precise. A 3-D analysis should possibly allow a better view at that point.

The height of throwing an object for distance involves projecting the object from a height. In that research, the height of the object was depended only on the height of the performer and not from the place related to the ground. Therefore, a tall performer had an automatic advantage over a shorter performer throwing with the same projection velocity of a shorter thrower. Also, the height of the performer was same with the average height of the elite discus athletes, as it has been mentioned by Georgiades (1991). From the present findings, it is obvious that the height of the performer (1.88m), combined with the given short distance which was needed to be reached, was pretty enough in reaching the level of the casualty. Apparently, lifesavers with the same height or taller, should not have any problem of applying that rescue technique for such distances.

The speed of release of a discus is possibly higher than the life preserver's one. This happens because the speed of release is the most influential determinant of the distance of the throw. When the distance is short, the speed is low too. In lifesaving, the life preserver throw technique usually is selected between a variety of other already mentioned methods, as the most effective in distances much less than 10m. When the distance exceeds 10m, the rope or throw bag throwing are more preferable and also suggested, followed by the 'row' and 'swim & tow' technique. Therefore, one might argue that there is not any similarity or comparability between the discus and the life preserver throw on the speed of release. Nevertheless, due to the lack of data, a comparison between discus and life preserver throw is not possible. The speed of release of 5.5-7.6m/sec in other throw events such javelin (Georgiades, 1991), is similar and therefore comparable with this of discus throw.

The horizontal distance increases with increases in the height of release. For the given distance of the 10m, the height of 2.04m from which the throw was developed, seems to serve properly the goals of the effort, and therefore there is not need of throwing higher than that height. On the other hand, a similar height of release (1.90-2.10m) has been refereed to exist among the discuss throws of elite athletes (Georgiades, 1991), supporting our finding. The scientific research in the future needs to find out the minimum and maximum limits for the height of release of the life preserver, for having successful throws. Finally, the angle of horizontal distance was 36.5^o, finding which seems to be related with that of the elite discus throwers, as it has been referenced by Georgiades (1991).

Conclusion

The present study found that the speed of release was 5.95m/s, which is among the limits of other throw events such as javelin and therefore is comparable. More research needs to identify the exact speed of release of discus, in order to better understand and compare it with the life preserver throw. More subjects need to take part in future research for establishing more integrated conclusions, relating to anthropometric variables. The lifesaver's height of 1.88m or above is enough for making a successful life preserver throw in the short distance of the 10m. The angle of horizontal distance of 36.5^o is needed in order to perform a life preserver throw. A height of release of 2.04m is enough for making a successfully rescue using the life preserver. Nevertheless, further research is required in order to identify the minimum and maximum limits which can be reached during the rescue attempt.

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