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Classification Efficiency in Wheelchair Rugby: Throwing Analysis

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Abstract: This study analyzed the ability of wheelchair rugby players to complete four commonly used passing techniques. A total of 15 athletes were tested and their data processed using KINOVEA sports performance analysis software and kinematic principles in order to derive quantitative performance indicators such as throw force, power and velocity for each of the passing techniques. Of particular interest to this study were the differences between athletes with and without triceps and those who had Deltoid - Triceps Transfer. The correlation between throwing abilities and current wheelchair rugby classification was also analyzed. Results showed that the entire no triceps group was able to throw using a chest pass and an impact pass; however only one third could perform the overarm passing technique and none were able to perform the sidearm pass technique. This group had an average throw distance of 4.8m. Furthermore, the deltoid-triceps participants were all able to throw a chest pass and an impact pass; however only one half could complete the overarm passing technique and none were able to perform the sidearm pass technique. This group had an average throw distance of 3.5m The group with triceps performed far better overall; with all participants being able to complete all throwing techniques with an average a throw distance of 8m. Finally, as expected, the able-bodied athletes performed the best of the four groups with an average throw distance of 12.3m. The triceps group had an average classification of 2, the no triceps group had an average classification of 0.5 and the deltoid-triceps transfer group had an average classification of 1. These current classifications are a good correlation when compared with the results of this study; except for the deltoid-triceps transfer athletes, who from the results of this study should have the throwing performance of a 0.5 point athlete.

1. INTRODUCTION

1.1 Motivation

Tetraplegia is complete or partial paralysis of four limbs of the body. Partaking in a sport like wheelchair rugby is a serious pursuit of many players and can greatly improve their quality of life. Thus, furthering research and the knowledge base around wheelchair rugby is important to a group of people who are passionate about their sport.

1.2 Purpose

The aim of this study is determine if there are differences in throwing ability between people with tetraplegia who either have natural triceps, no triceps or deltoid-triceps transfers (DTT).

1.3 Deltoid - Triceps Procedure

Deltoid – Triceps surgery is a reconstructive upper limb surgical technique that is performed world-wide. This surgery enables people with tetraplegia to actively extend their arms when previously they had no, or very weak, natural triceps function. In New Zealand, a high percentage of people with tetraplegia, for whom this procedure will benefit, are electing to have the procedure.

Currently there is conjecture around the classification of athletes who have had this surgery and whether their ability to extend their arms can be compared to natural triceps.

1.4 Wheelchair Rugby Classification

In wheelchair rugby each athlete is classified from 0.5 points to 3.5 points depending on their functional ability to perform technical aspects of the sport. The 0.5 class includes those athletes with the most disability and the 3.5 class includes those athletes with the least disability or “minimal” disability eligible for the sport of wheelchair rugby. (IWRF, 2013). Each four person team must have a summation of 8.0 or less points on the court at a time.

At present, classification involves a qualitative assessment of a person’s functional muscle capability but involves no quantitative analysis. As this qualitative assessment is a subjective evaluation there can be conflicting conclusions drawn on an athlete’s classification.

1.5 Throw Testing

In a wheelchair rugby game context, throwing ability is vital as this dictates whether a player can either be a ball carrying playmaker or simply run interference on the court.

2. RESEARCH AND LITERATURE REVIEW

2.1 Different Passing Techniques in Wheel-chair Rugby

The four most widely used passing techniques in wheelchair rugby are: 1) chest pass, 2) over arm throw (or grid iron pass), 3) side-arm throw and 4) one handed impact pass (Goosey-Tolfrey, V. 2010, p. 152).

2.2 Different Muscle Groups Activated when Passing in Wheelchair Rugby

The different muscle groups involved in completing these throwing sequences include: the trapezius, pectoralis major, deltoid, biceps, triceps, brachialis, flexor capi radialis, flexor carpi-ulnaris and hypothenar muscles (Kenneth S. Saladin 2010, n. pag.). In addition trunk muscle groups are used to stabilize the body.

Athletes with tetraplegia will have varying innervation of these muscle groups, for example a large majority of the athletes (classification between 0.5 points or 2.5 points) will have limited stabilizing muscles active in their trunk, weakened chest muscles, limited bicep and triceps, and limited hand and wrist function.

2.2 Discretization of the Four Groups

Group 1). Athletes with natural biceps function; however only weak proximal shoulder strength, weak or zero natural triceps functionality, very limited wrist extension, and no digit mobility (athlete classification of 0.5 points, and 1.0 points, respectively). This group will be termed "No Triceps".

Group 2). Athletes with slight shoulder strength, natural biceps function and natural triceps function; however, limited wrist extension, and limited digit mobility (athlete classification of between 1.5 points and 2.5 points, respectively). This group will be termed "Triceps".

Group 3). Athletes with slight shoulder strength, natural biceps function, deltoid-triceps transfer triceps function; however limited wrist extension, and limited digit mobility (athlete classification of between 0.5 points and 1.5 points). This group will be termed "Deltoid – Triceps Transfer (DTT)".

Group 4). Able bodied athletes (athletes with no disability).

2.3 Related Literature

The significance of classification on game efficiency in wheelchair rugby has led many researchers to analyse the classification process. In particular, the qualitative nature of the classification methods has driven many researchers to evaluate and attempt to improve the methodology of athlete classification. The performance of wheelchair rugby athletes completing five performance specific tests has previously been analysed (Malone, Orr and Collins, 2006). The tests were 20m sprint, endurance sprint, up and back and slalom; with the results evaluated against the athlete classifications. Malone, Orr and Collins discovered a correlation between performance and classification; while reporting significant differences among the lower classification groups, 0.5 to 2, and between these groups and the higher classification groups, 2.5-3.5. A study undertaken during the 2008 Paralympic Games analysed classification efficiency in wheelchair rugby by reviewing game statistics (Morgulec and Kosmol, 2010). This involved analysing individual athlete's statistics which included; points scored, pass assists, assisted blocks, turnovers and steals. Testing while an athlete is competing is valuable as the athlete is more likely to play with maximum effort. In a testing situation it is advantageous for an athlete to perform within their own capability in order to lower their classification. Morgulec and Kosmol also identified a positive correlation between classification and performance; while revealing the greatest difference between the 0.5 point group and the other groups. The work of Morgulec and Kosmol, and Malone, Orr and Collins evaluated the classification efficiency of wheelchair rugby and introduced quantifiable attributes to judge athletes abilities on. However, very few studies have specifically tested the performance of throwing and the correlation between throwing ability and classification of athletes. Additionally, there is very little information available involving the comparison between athletes who have had a deltoid-triceps transfer procedure and athletes who have not.

3. PROCEDURE

3.1 Ethics

Consent to conduct testing with people with tetraplegia was granted under the Ethics Approval from the University of Otago (ref 13/042), New Zealand, held by the project supervisors Dr. Jennifer Dunn and Dr. Shayne Gooch who were present at testing and obtained consent from test subjects.

3.1 Participants

Participants were recruited at two wheelchair rugby tournaments and one local wheelchair rugby training location in New Zealand. Participants were eligible to participate if they were classified wheelchair rugby athletes.

The able bodied participants were students recruited from the University of Canterbury and were tested from a sitting position in rugby wheelchairs.

A total of 13 people with tetraplegia were tested, 8 had triceps, three had no triceps, and two had received the deltoid-triceps transfer (DDT). The triceps group had an average classification of 2.5, the no triceps group had an average classification of 0.5 and the DTT group had an average classification of 1.0.

3.2 Experimental Procedure

A reproducible and valid experimental procedure was created which involved the athletes completing the four throwing techniques three times each whilst video cameras recorded their throwing technique and the balls flight path.

This procedure was trialled on able bodied students from the University of Canterbury. From this trial the procedure was analysed and improved in order to better accommodate the subjects being tested, and to increase the efficiency of the testing process utilized on the athletes with tetraplegia.

4. PROCESSING

4.1 De-identifying Participants

Participants were allocated into one of the four groups depending on their triceps function. They were then given a unique identifier to maintain their anonymity during the analysis.

4.2 KINOVEA Sports Analysis

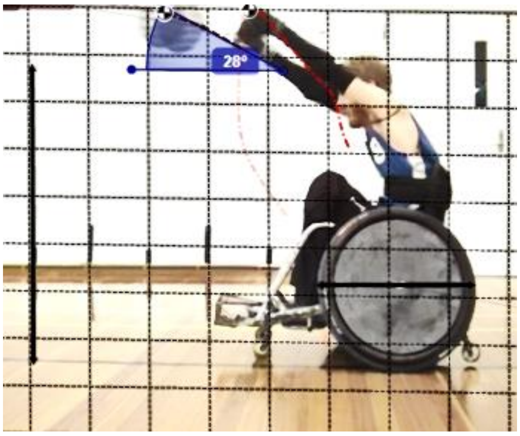

Figure 1-Processed throw after KINOVEA analysis

The throw footage was processed using the sports performance analysis software KINOVEA to gain trajectory, throw time, flight time and tracked velocity information for each of the athletes throws. This information allows quantitative performance indicators to be derived (figure 1).

4.3 Kinematic Study

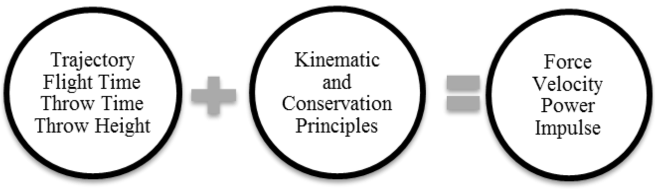

Figure 2-Proccessing flow chart

The information gained from KINOVEA was analysed using kinematic and conservation principles to translate these measurements into quantitative KPI's (Key Performance Indicators) including throw force, throw power, pass velocity, impulse and distance (figure 2).

The kinematic theory that was used to establish initial and final velocity values of a thrown ball is as follows:

Assuming constant acceleration the first kinematic equation states

$$\mathrm{Vf} = \mathrm{Vi} + \mathrm{at} \quad (1)$$

This equation (1) projected in the y direction is

$$\mathrm{Vf}.\check{j} = \mathrm{Vi}.\check{j} + \mathrm{at}.\check{j} \quad (2)$$

Where $\check{j}$ is a unit vector pointing in the vertical y direction.

In terms of throwing a ball; after release the only acceleration is the constant acceleration of gravity in the downward direction. At the time of maximum height the vertical velocity is equal to zero.

$$g = -9.81\mathrm{ms}^{-2} \quad (2.1)$$

$$\mathrm{V(Hmax)}.\check{j} = 0 \quad (2.2)$$

Where $V_{(Hmax)}\check{j}$ is the vertical velocity at time of maximum height.

Equation (2) as related to this ball throw context;

$$\mathrm{V(Hmax)}.\check{j} = \mathrm{Vrel}.\check{j} + g \times \mathrm{t(Hmax)} \quad (3)$$

Where Vrel.$\check{j}$ is the vertical velocity of the ball when released.

Which can be re-arranged using (2.1) and (2.2);

$$\mathrm{Vrel}.\check{j} = -(-9.81\mathrm{ms}^{-2}) \times \mathrm{t(Hmax)} \quad (4)$$

Using trigonometry, values for release velocity in the direction of flight and horizontal can be determined;

$$\mathrm{Vrel} = \mathrm{Vrel}.\check{j}/(\sin(\alpha)) \quad (5)$$

Where α is the angle of throw trajectory.

$$\mathrm{Vrel}.\check{i} = \mathrm{Vrel}.\check{j}/(\tan(\alpha)) \quad (6)$$

Where Vrel.$\check{i}$ is the horizontal velocity of the ball.

5. EXPECTED RESULTS

5.1 Group 1). No Triceps

It is expected that this group will measure the lowest across the KPI's of each throwing technique due to their extent of innervation of key muscle groups in the upper limb and trunk. In particular, their lack of wrist and finger mobility, lack of triceps capability and limited pectoral strength will affect their throwing ability.

5.2 Group 2). Triceps

It was expected that this group would measure the highest of the three groups' with tetraplegia. That they would measure well over all KPI's but in particular would show superiority in the grid iron throw and chest pass techniques. This is due to their natural triceps capability and wrist and finger mobility allowing increased grip and push power which are particularly vital in completing these two techniques.

5.3 Group 3). DTT Assisted Triceps

It is expected this group's performance will be between that of group 1 and group 2. This is due to their muscle innervation that is similar to the no triceps group except for improved elbow extension provided by the DTT procedure. It is known that the elbow extension strength is less than that of natural triceps strength, but more than having no triceps. It is expected that they will show greater chest pass performance and greater grid iron and side arm throwing than group 1.

5.4 Group 4). Able Bodied

It is expected that this group will have superior KPI's with all throwing techniques. This is due to their full strength of upper limb muscles as well as trunk stabilisation.

6. QUANTITATIVE RESULTS

All participants were able to complete the chest pass. Only particicants with triceps were able to complete the side arm pass. Additionally, only one third and one half of the no triceps and DTT groups' could complete the grid iron passing technique, respectively.

6.1 Throw Distance

Participants completed three passes of each throwing technique and the throw distance was calculated as an average of these three throws. As some of the athletes could not perform all of the throwing techniques only those who completed the pass were accounted for in the average calculations.

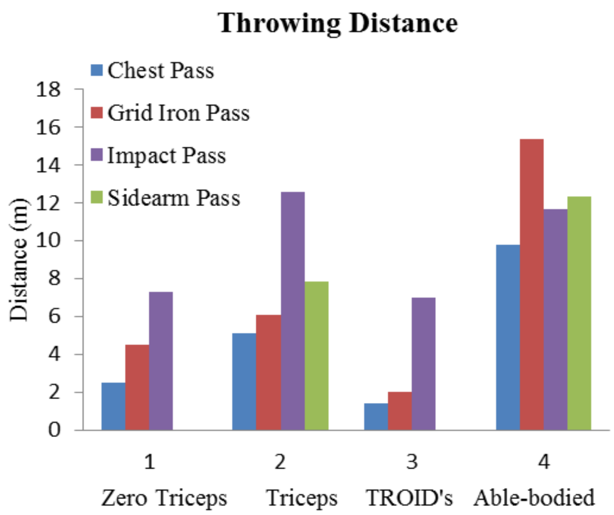

Figure 3- Average throwing distance of each passing technique achieved by the groups of athletes.

The able bodied population was able to throw greater distances than the tetraplegic population in all techniques exept for the impact pass. Between the groups with tetraplegia, the triceps group were able to throw greater distances than the no triceps and DTT groups in all techniques. The no triceps group were able to chest pass and grid iron pass better than the DTT group and both groups were able to impact pass similar distances (figure 3).

6.2 Throw Velocity

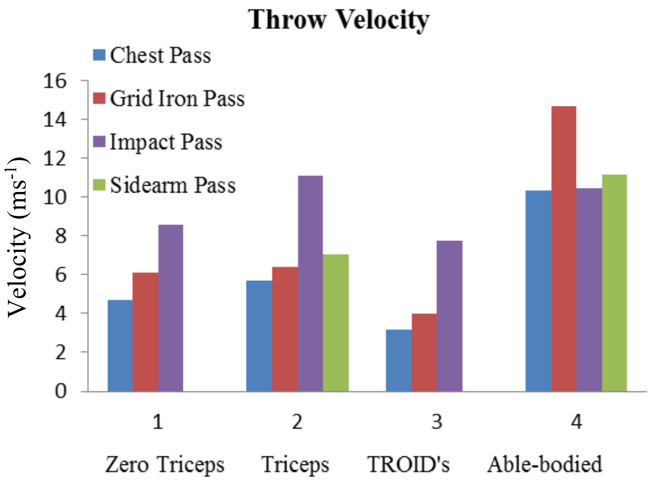

Figure 4- Average throwing velocity of each passing technique achieved by the groups of athletes.

The able-bodied group measured the greatest throw velocity realative to the tetraplegia groups. Between the tetraplegia groups, the triceps group were able to throw with greater velocites than the no triceps and DTT groups in all techniques. The no triceps group achieved faster throing speeds when compared to the DTT group (figure 4).

6.3 Throw Force

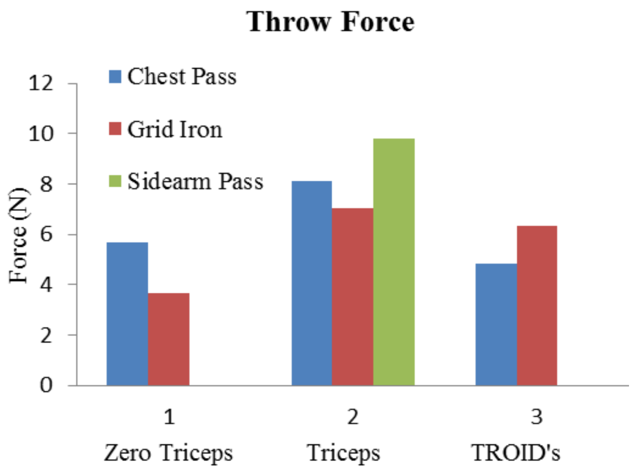

Figure 5- Average throwing force of each passing technique achieved by the three groups of athletes with tetraplegia.

As force is not an appropriate unit of measurement for an impact collision this pass was not analysed in this section. The results show that the triceps group have the greatest throw force across all three techniques compared to the zero triceps and DTT group. Overall, the no triceps and DTT group had similar throwing force with the no triceps group being better at the chest pass and the DTT group better at the grid iron pass (figure 5).

7. QUALITATIVE RESULTS

7.1 DTT Assisted Triceps and No Triceps

The DTT and no triceps groups were much slower in executing every facet of a throw relative to the natural triceps group. These athletes spent twice as long loading before throwing the ball, had far slower hands during the throwing action and often had to re-adjust during a throw.

Technically the DTT and no triceps groups were similar in their performance of all the passing techniques. Neither demonstrated any trunk stability to their throws. Participants in both these groups struggled to hold the ball with one hand, had relatively weak throwing arcs when compared to triceps group. Thus, the majority could not perform the one handed grid iron pass.

7.2 Triceps

The natural triceps group had some torso input, had significantly quicker hands and had some wrist flick which increased the accuracy and distance of their throws. Some of these athletes still had trouble holding the ball in two hands; however, and would occasionally need to re-adjust. This group were able to complete all throwing techniques and seemed comfortable throwing with different trajectories.

7.3 Able Bodied

The able bodied group had rapid acceleration during propulsion, handled the ball with ease and their finger mobility led to well directed throws compared to the tetraplegia population. The extent of their trunk activation during throwing was noticeable which led to a more powerful throw despite this group performing the passing in a seated position. Participants in this group were able to complete the throws with a flexible release point and with varying trajectories.

8. DISCUSSION

8.1 Key Result

A total of 15 athletes were tested from four different groups; no triceps, triceps, DTT assisted triceps and able bodied. Their respective tests were then processed using KINOVEA sports performance analysis software and kinematic principles quantitative in order to derive performance indicators such as throw force, power and velocity.

It was found that the no triceps group performed better than the DTT group averaging a distance of 4.8m over all the throwing techniques as opposed to the 3.5m achieved by the DTT group. While this was a surprising result a more detailed clinical review of each participant is required to interpret the significance in terms of improving the the transfer procedure does not significantly improve the athletes' ability to pass in wheelchair rugby. The triceps group performed far better achieving an average distance of 8m, and finally as expected the able-bodied athletes performed the best with a distance 12.3m.

The triceps group have an average classification of 2, the no triceps have an average classification of 0.5 and the DTT have an average classification of 1. These current classifications correlate positively with the results of this study except for the DTT athletes who, assuming equal propulsion performance compared to the no triceps group, could be classified too high.

8.1 Validity

8.1.1 Experimental Procedure

The experimental procedure was reproducible and conducted thoroughly on each participant. Two different people checked the distance thrown; this was additionally checked by analysing the throw footage on KINOVEA, and finally by using kinematic principles. Additionally, the force and power values calculated for each athlete were able to be compared to the push strength testing of the athletes, which ran parallel to this study, in order to compare trends between athletes and further check the procedure for any irregularities.

8.1.2 Human Input

There are inherent irregularities due to having human subjects who will never output the same amount of energy as one another.

8.1.3 KINOVEA

There are errors accumulated during the calculations of power, force and impulse. These values were derived using KINOVEA sports performance analysis tools which have some associated errors. The KINOVEA stopwatch is limited by the frames being 0.03 seconds apart and therefore each time measurement has an error of ±0.015 seconds. The KINOVEA length measurements require a reference length to calibrate against. The wheel diameter of each respective wheelchair was used as this reference. These wheels do not lie in the same plane as the throw and therefore may create some parallax error. Additionally, these were calculated as time averaged values which are fine for the purpose of comparison but are not maximum values. Also the drag effects of the ball were neglected due to the low ball speed achieved. None of these have significant influences on the results and therefore are not considered to compromise the validity of the experiment.

8.1.4 Quantitative Results

An abnormality lies in the able bodied group's impact pass which was less than that of the triceps group. This pass is technically challenging and not widely used outside wheelchair rugby; therefore, this result is influenced by the fact that the triceps group were more practiced and had better learnt a technique resulting in a greater distance than the able bodied group

The throw velocities did not differ between the groups to the same extent as the other performance indicators. This means there must be a difference in trajectories between the groups, and that throw distance is heavily reliant on the trajectory. The differing functional abilities of athletes meant that their ability to lift their arms was limited and this affected the trajectory.

There is a positive correlation between the classification and throwing performance of the athletes tested.

8.1.5 Qualitative Results

The speed and accuracy of the triceps group in completing their passing manoeuvres means they can be effective wheelchair rugby playmakers. These athletes' are more difficult to shut down as they have a variety of passes available and can complete these passes relatively quickly allowing them to move the ball on before being confronted by an opposition player.

8.1.6 Sample Size

While the sample size of 15 athletes is small and did not allow for statistical analysis, we were able to demonstrate trends between the three groups. As there was little intra-group variation we feel that these trends are reliable and useful in analysing the efficiency of the classification of athletes within wheelchair rugby.

9. CONCLUSION

While it is known that recipients of deltoid-triceps transfers increase their elbow extension strength in transfer from very limited to being able to extend their elbow against gravity, it is not known how this ability can be translated into function during wheelchair rugby. This study aimed to determine the differences in throwing ability between wheelchair rugby athletes who had triceps, no triceps or deltoid-triceps transfers. The results demonstrated that the athletes who had active elbow extension provided by the DTT showed lesser throwing capability across all throwing techniques than those with no triceps. This highlights the fact that the current classification is disadvantaging teams that include people with the DDT for triceps. They are still not able to compete in playmaking, ball handling roles within wheelchair rugby like athletes who have natural triceps function. This study suggests that in terms of throwing capability these athletes are no more able than the no triceps group and cannot be compared to those athletes with natural triceps function.

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Appendix B. Derivation of Force and Power

FORCE

$$F = ma \qquad (1)$$

This can be mathematically represented as;

$$\mathrm{F} = \lim_{\mathrm{t2}\to\mathrm{t1}} \mathrm{m}\left(\frac{\mathrm{V2}-\mathrm{V1}}{\mathrm{t2}-\mathrm{t1}}\right) \qquad (2)$$

Therefore an average force exerted between two times;

$$\mathrm{Favg} = \mathrm{m}\,\frac{(\mathrm{V2}-\mathrm{V1})}{(\mathrm{t2}-\mathrm{t1})} \qquad (3)$$

Described in terms of force of a given throw;

$$\mathrm{Favg} = \mathrm{m}\,\frac{(\mathrm{Vrel}-0)}{(\mathrm{t(rel)}-\mathrm{t0})} \qquad (5)$$

Where Favg is the average force exerted on the ball during the power phase of a throw, Vrel is the velocity immediately after release, t(rel) is the time at release and t0 is the time at initiation of the power phase of the throw.

POWER

The power of a throw can be calculated from the energy of the ball before and after the power phase of a throw with the time taken to complete the throw.

$$\mathrm{Power} = \text{rate of change of energy} = \mathrm{dE/dt} \qquad (1)$$

$$\mathrm{Ek} = ½\,\mathrm{m}\,V^2 \qquad (1.1)$$
$$\mathrm{Ep} = \mathrm{mgH} \qquad (1.2)$$

$$\mathrm{Power} = (\Delta\mathrm{Ek} + \Delta\mathrm{Ep})/\,(\mathrm{t2}-\mathrm{t1}) \qquad (2)$$

Where ΔEk and ΔEp is the change in kinetic and potential energy.

Substituting (1.1) and (1.2) into (2) and re-arranging;

$$\mathrm{Power} = \frac{\mathrm{m}\left[\frac{(\mathrm{V_2}-\mathrm{V_1})^2}{2}+g(\mathrm{h_2}-\mathrm{h_1})\right]}{[\mathrm{t_2}-\mathrm{t_1}]} \qquad (3)$$

In terms of the throw context;

$$\mathrm{Power} = \frac{\mathrm{m}\left[\frac{(\mathrm{V}_{release}-V_0)^2}{2}+g(\mathrm{H}_{release}-\mathrm{H_0})\right]}{[\mathrm{t}_{release}-\mathrm{t_0}]} \qquad (4)$$

Where H_0 is the height of the centre of the ball at the initiation of the propulsion phase of the throw, $H_{release}$ is the height of the centre of the ball at the point of release, V_0 is the velocity of the centre of the ball at the initiation of the propulsion phase of the throw, t_0 is the time at the initiation of the propulsion phase of the throw.