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Letter-to-Editor

A load-velocity relationship for men and women in overhead throwing performance

Dear Editor-in-Chief

In many movements, resistance (load) and velocity are inversely related to each other (Schilling et al., 2008). This relationship is often ascribed to skeletal muscle properties. Hill (1938) described a hyperbolic relationship (Hill's curve) between force and velocity for isolated muscles. Many other researchers in muscle physiology as well as researchers in the more applied sciences used this association to describe and explain phenomena of muscle contraction. In sport science, many training studies, set up to enhance the performance of the athlete, are based on Hill's curve (e.g. Schilling et al., 2008; van den Tillaar and Ettema, 2004).

For throwing performance, several studies showed that by increasing ball mass ball velocity at release decreases (Kunz, 1974; Toyoshima et al., 1976; Toyoshima and Miyashita, 1973; van den Tillaar and Ettema, 2004). However, all studies used only a small range of ball mass varying from 0.08 to 0.8 kg and thereby indicated a linear relationship between velocity and ball mass; while using a wider range probably a hyperbolic relationship would be found like in isolated muscles.

Overhead throwing is used in soccer throw-in, in resistance training for throwing events and also in other sports training. Van den Tillaar and Marques (2009) showed that training with soccer balls and medicine balls (5kg) could positively influence throwing performance. They based their findings on the principal of the force-velocity relationship of muscles. However, to our best knowledge, no previous studies have shown what type of relationship can be observed between throwing with ball masses varying from 0.45kg (soccer ball) to 5kg in two handed overhead throwing velocity. Furthermore, most previous studies used men as subjects on which they based their load-velocity relationship upon.

Therefore, the aim of this study was to investigate the load-velocity relationship in overhead throwing with different ball mass varying from 0.45kg to 5kg for both men and women. It was hypothesized that the load-velocity relationship was hyperbolic and not linear as found in earlier studies (Kunz, 1974; Toyoshima et al., 1976; Toyoshima and Miyashita, 1973; van den Tillaar and Ettema, 2004).

Eighty (56 men and 24 women) university students of sport science (age 21.7 ± 2.1 y, mass 71.5 ± 11 kg, height 1.75 ± 0.09 m) participated in this study. Before participating in this study, the subjects were fully informed about the protocol. Informed consent was obtained prior to all testing, in accordance with the recommendations of local ethical committee.

The present study used a cross-sectional experimental design to examine a load-velocity relationship in overhead throwing for men and women. The load-velocity relationship was established by using four different weighted balls varying from 0.45kg to 5kg. Two-handed overhead throwing was used, since most subjects had some experience with this specific throwing technique with medicine and soccer balls. In addition, two-handed medicine ball throwing mimics the same throwing movements (as soccer) with only a weight difference. According to van den Tillaar and Marques (2009) the two-handed overhead throwing technique limits the degrees of freedom that are possible to use (i.e. trivial rotation along the longitudinal axis). Thereby, the performance is less dependent on technique differences between subjects.

Before the test the participants practiced in throwing with the different weighted balls. This activity was undertaken to avoid a learning effect. Four balls with different mass were used in the test: a soccer ball (circumference 0.68m; regular mass 0.45kg), a 1kg medicine ball (circumference 0.72m), a 3kg medicine ball (circumference 0.78m) and a 5kg medicine ball (circumference 0.85m). After a general warm-up of 10 minutes, which included of throwing with different weighted balls to warm up the shoulders, throwing with the different ball was tested. The same procedure was used as in the study of van den Tillaar and Marques (2009). The participant stood with both feet parallel to each other while throwing the balls. All participants started with holding the ball in front of them with both hands. They were instructed to throw the medicine ball as far and fast as possible with both hands over their head and hyper-extending their back and shoulders (soccer throw-in movement). Both feet were kept in contact with the ground at all times during and after the throw and no preliminary steps were allowed. Torso and hip rotation was also prohibited. When a participant did not keep both feet on the ground during the throw the attempt was not approved and a new attempt was performed. An expert in throwing controlled this aspect of the study.

Three approved attempts were made with each ball with one-minute rest between each attempt. The sequence of ball type was randomized for each participant to ensure that fatigue or learning effects did not alter the performance. The maximal velocity with each ball was determined using a Doppler radar gun (Sports Radar 3300, Sports Electronics Inc.), with ± 0.03m/s accuracy within a field of 10 degrees from the gun. The radar gun was located 1m behind the participant at ball height during the throw. Only the best attempts with each ball were used for further analysis.

To assess a relationship of ball mass on velocity of the ball in men and women curve estimation was performed in (SPSS 14.0) where a linear and a logarithmic

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Table 1. Linear and logarithmic curve estimates between ball mass and ball velocity for men and women.

Equation	Model Summary (men n=56)			Model Summary (women n=24)		
	R^2	F	Sig.	R^2	F	Sig.
Linear	.908	19.686	.047	.906	19.193	.048
Logarithmic	.997	791.973	.001	.998	935.976	.001

model was used.

It was found that the logarithmic model for both men and women fitted the data much better than the linear model (Table 1, Figure 1). It showed to be a high significant correlation between ball mass and throwing velocity for men (p=0.0013) and women (p=0.0011) i.e. when the ball mass increased the throwing velocity decreased hyperbolic. While using the linear model the relationship just reached the significance level of $p<0.05$. In addition, when applying the model to compare when men and women it is found that by increasing the ball mass the differences in throwing velocity between gender becomes less (figure 1).

The aim of this study was to investigate the relationship between load and velocity in overhead throwing in both men and women. The results confirm earlier studies (Kunz, 1974; Toyoshima et al., 1976; Toyoshima and Miyashita, 1973; van den Tillaar and Ettema, 2004) and indicated that an inverse relationship between load and velocity exists. In other words, high ball velocities are obtained with low load (ball mass). However, this is the first study that has examined the relationship between throwing velocity with ball mass varying in both genders from 0.45kg to 5kg. In earlier studies on throwing a linear relationship was found between ball mass and ball velocity (Toyoshima et al., 1976; van den Tillaar and Ettema, 2004). However, they based their relationship upon a small range of ball mass. If they would use a larger ball range they would probably find a curvilinear relationship as we did in overhead throwing.

Although the load-velocity relationship of our study and isolated muscle contraction may be similar, the systems and actions from which these performance curves arise are quite different (e.g., complexity of the movement, the number of factors like motivation, muscle activity levels, muscle synergies and coordination and system elements like nervous system, various muscles and joints, that are involved). One should therefore take extreme care by interpreting the current load-velocity curve as being mainly determined by muscle properties (van den Tillaar and Ettema, 2004).

That the difference in ball velocity with the lighter balls (0.45kg) between men and women was bigger than with the heavier medicine ball (5kg) and thereby indicating a different load-velocity curve can be explained by throwing experience. Toyoshima and Mihashita (1976) showed that 6-year-old boys had smaller difference in maximal ball velocities when throwing with different ball masses (0.1 to 0.5kg) than 15 year old boys or adults had. Adults showed a difference of around 9m/s when comparing throws with balls of 0.1kg and 0.5kg of mass while 6-year-old boys only showed a difference of around 4m/s. Toyoshima and Mihashita (1976) suggested that the throwing pattern of younger subjects is not fully developed. In our study this could also be a reason for the differences between the results of the men and women.

We only used 4 different ball masses to base the relationship upon. To get a more accurate relationship it would be better to have more points i.e. throwing with several different ball masses. However, we wanted to avoid that fatigue would influence the results. When applying the model to men and women we found that by increasing ball mass the difference in ball velocity between genders decreases. Differences in hormonal,

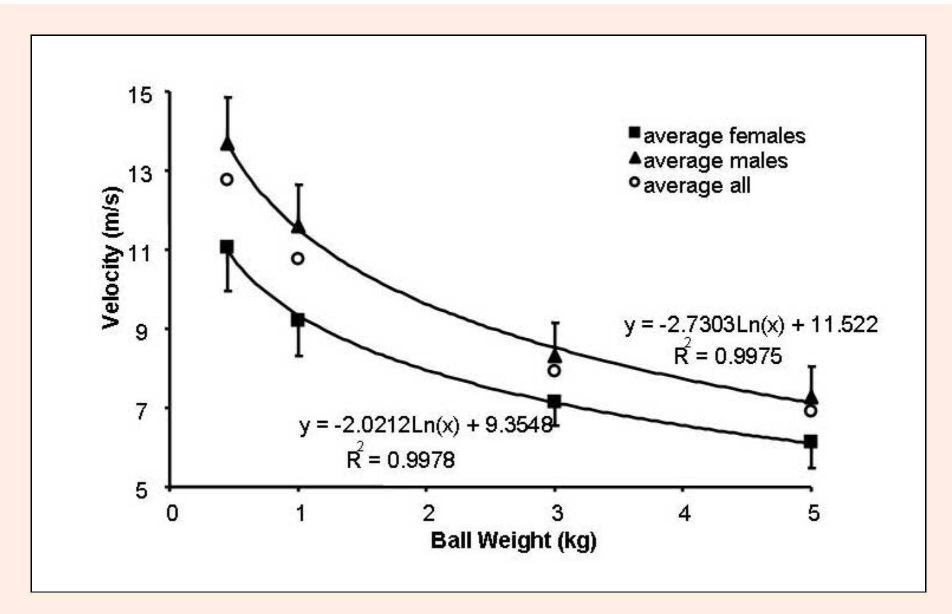

Figure 1. Relationship between ball mass and maximal ball velocity for men and women based on ball mass varying from 0.45 to 5kg.

enzymatic and neurological factors, limb lengths, coordination patterns, muscle mass and the fact that women tend to have a lower proportion of their lean tissue distributed in the upper body could explain the greater gender-differences in upper body strength (Abe et al., 1998).

A practical application that can be suggested based upon the findings of our study is that women can train relatively slightly heavier when training for velocity because velocity doesn't decline at the same rate as throwing mass increases. In fact, the curve was less steep for women and may represent gender differences, for example, on mechanical throwing performance. It could be also suggested that the dominance in women of type I muscle fibers and a difference in the degree of inhibition in the nervous system may be related to the gender difference in throwing performance, special at higher velocities.

Explosive strength is a fundamental aspect of many sports and has become an essential aspect of most training programs. The need for a quick and convenient method of measuring power is ongoing. Indeed, the classic force-velocity curve for isolated muscle seems to be applicable in throwing tasks with different loads, suggesting that some strength training programs can also be applied in these throwing tasks. However, in the current study no force output was measured to establish a force-velocity relationship for this throwing movement. Future studies should be designed to measure the force to get more information about the relation between force and velocity in these types of movements.

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