AN ANALYSIS OF BRUSHING STUDIES

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With curling now an Olympic sport, coupled with technological advances that permit more detailed analysis than possible even a few years ago, curling is now being studied as never before. Research teams from Canada [5,6,14], Russia [4], Finland [3], Sweden [11-13], and Japan [7-9, 15-19] have for several years been studying the physics of curling and searching for models that explain the motion of a curling stone, or the impact of brushing upon a curling stone. The bibliography at the end of this article is far from exhaustive; our collection of curling articles from the academic literature contains over 50 papers, the earliest from 1924 [2].

One of the issues in looking at the extant literature for the sport of curling is that the overall number of studies of athletes has been small, and moreover the sizes of the studies has been small as well. The small number and sample sizes of studies can lead to lack of confidence in the results of these studies being representative of the true results of the larger population of curling athletes. This is due to both the increased statistical uncertainty when using a small number of samples, as well as inherent bias in selecting a small number of athletes. For studies involving human performance, these statistical problems are further amplified by the large variability in human performance itself. For example, would four front end players from the top Canadian men’s curling teams be representative of all competitive curlers? Also, would their results be able to predict results for all club curlers? Conversely, would the results of a study on four 17-year-old athletes be representative of all 17-year-old athletes, all under-21 athletes, or all curling athletes? As a result, it is clear that some studies suffer from statistical limitations, and others can provide somewhat misleading conclusions as the paper's results are taken from a very small sample of athletes.

In this article, we look at two articles from the literature [1,10] and analyze their results, beginning with the description of an Olympic athlete’s brushing performance provided by Marmo, Buckingham, and Blackford in 2006 [10].

In this first article, Marmo et al. [10] describe the brushing performance of a single unnamed male Olympic athlete, presumably from the Scottish national team. Neither the playing position, nor the physical characteristics (notably body weight) of the player are given, but their brushing performance curves are illustrated in the figure below, taken from the paper, and the paper describes the athlete's performance as one with a mean stroke rate of approximately 4.5Hz, and a mean maximum vertical force of 450 Newtons. A Newton is the amount of force needed to accelerate 1 kilogram of mass at the rate of 1 metre per second squared. As many readers are unfamiliar with Newtons as a measure, we can translate easily a vertical force measured in Newtons into a gravitational measure, kilograms, simply by dividing the force in Newtons by the gravitational constant g = 9.81. Hence 450N becomes 450/9.81 or 45.88kg, or, converting to English pounds, 100.95lbs of vertical force on the brush.

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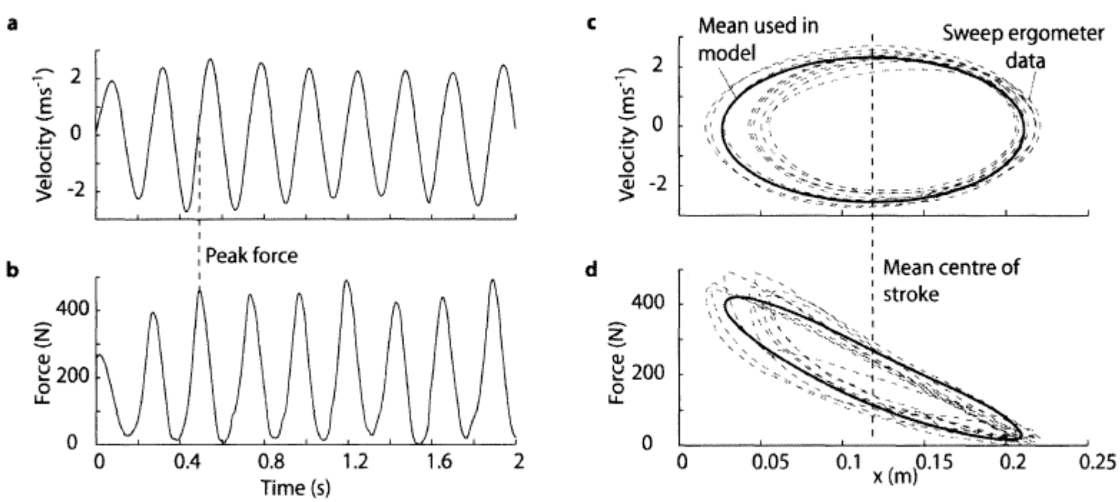

Fig. 2. Velocity and force recorded from an Olympic level male curler with the sweep ergometer. a) Horizontal velocity-time history. b) Vertical force-time history. Peak velocity and force do not coincide. c) Variation of velocity with position for a curler who's centre of mass is close to the origin. d) Variation of vertical force with position. Solid line shows the mean used in the numerical model (see Fig. 4).

Above is the force curve taken from Figure 2 of Marmo's paper. Note the mean minimum force is quite close to zero for the section of the force curve presented. Although only a portion of the force curve for a complete bout is shown, we can hypothesize that the athlete's mean force is approximately 240N. Using the identical arithmetic to that used previously, 240N is equivalent to 24.47kg, or 53.84lbs.

Unfortunately, Marmo et al. do not describe the physical characteristics of the male athlete featured in their paper, but for sake of argument let us assume that this male athlete had a body weight of 170 lbs. If so, this means that:

1. the athlete's normalized mean maximum force (in lbs) is 100.95/170, or 59.38%.
2. the athlete's normalized mean force is 53.84/170, or 31.67%.

The problem is that neither of these two figures is anywhere close to top-notch brushing performance by a male athlete, assuming a body weight of 170 lbs. A normalized mean brushing force of 31% is significantly below average for top-ranked competitive Junior men, given the 600+ athletes that the authors (John Newhook and Glenn Paulley) have measured over the past four years. Note that, even if the athlete featured in the study weighed less – say 150 lbs – then his normalized mean force would be 53.84/150 = 35.89%, still below average for a typical male U21 athlete and considerably below the results for top competitive athletes that we have measured over the past four years.

Our second example is from Bradley [1], where, in his very well-written paper on the physics of curling, Bradley offers summary data for 17 elite, competitive athletes (5 male, 12 female). The sparse metadata for these athletes is shown below, taken from [1], Table 2:

Table 2. Typical results from 17 elite competitive curlers (5 male, 12 female) performing 20s periods of hard sweeping (mean (SD)).

	Average Sweep Length (m)	Average Sweep Rate (Hz)	Average Total Work (kJ)	Average Heart Rate (bpm)	Vertical Force (N)
Male	.1071 (.013)	4.32 (.66)	1538 (522)	169 (16)	146.3 (29.0)
Female	.1071 (.024)	3.81 (.37)	663 (301)	164 (16)	81.7 (17.7)

Unfortunately, Bradley provides only summary data for the sets of male and female athletes, so, as outlined in the table above, we are left to work with averages. It is difficult to conclude much in the way of results given the small number of males included in the study (5), and some hint to this is given by the remark that

> "Vertical force generated by male curlers however was nearly double that generated by female curlers (Table 2). This led to the vertical force in successive 20s bouts of hard

> sweeping falling significantly in male curlers but being more consistent in female curlers (Figure 4)."

which does not match our experience in testing.

Without knowing the body weights of the athletes tested it is impossible to tell if these are truly "elite" athletes with respect to brushing – but we can conjure an analysis with some reasonable assumptions. For the male athletes in Bradley's study, we assume once again a mean body weight of 170lbs. As given in Bradley's Table 2, the mean vertical force in Newtons was 146.3, or 32.82 lbs. This results in an average normalized mean force of 19.3%, once again considerably below average to what we (Newhook and Paulley) have tested over the past four years. Again, if we assume a lower mean body weight of 150lbs, then this normalized mean force increases to 21.88%, which is still well below average for **any** competitive age group. Even the mean value of vertical force itself (146 N) is only 60% of the mean value for the athletes in Marmo's [10] study, confirming the small sample size issues.

If we turn to the female athletes, Bradley gives their mean force as 81.7 Newtons, or 18.33 lbs. If we assume the average body weight of the female athletes as 120lbs, then the female athletes' normalized mean force, on average, is only 15.2%. Between us, the authors (Newhook and Paulley) have tested many female athletes with considerably greater normalized mean force than 15%. Top female athletes brush with greater than 40% normalized mean force, often exceeding mean force values of 225 N, or 50 lbs.

Regrettably, we have no knowledge of the particular brushing techniques used in either of these studies – for example, whether or not the athlete(s) used a slider while brushing. However, it is clear that the vertical force values reported in these studies are low, and our studies of 600+ athletes over the past four years indicates that these vertical force values can be quite easily eclipsed by many U18 and U21 athletes. A brief summary of our testing, along with targets for athletes of both genders at different LTAD stages, can be found in "Brushing Definitions and Targets", the fourth article in this Series.

Every study adds to awareness, knowledge and understanding. The work reported by Marmo et al. and by Bradley were important early studies that contributed to our understanding of the physics occurring during brushing, as well as the ability to measure with on-ice devices, specifically instrumented curling brooms. The fact that the data is limited points to the need to for more testing to be conducted. We encourage more scientific studies to be undertaken on all aspects of brushing.

We look forward to the research recently conducted by Sean Maw and his research team at the University of Saskatchewan, spearheaded by former Saskatchewan champion Eugene Hritzuk, that will hopefully shed some additional light on the physics of brushing.

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QUESTIONS

We are pleased to provide whatever assistance we can to coaches and athletes. Our contact information is below.

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