Consistency of swimming performance within and between competitions

ANDREW M. STEWART and WILLIAM G. HOPKINS

Scottish Institute of Sports Medicine and Sports Science, University of Strathclyde, Glasgow, SCOTLAND; and Department of Physiology, School of Medical Science, University of Otago, Dunedin, NEW ZEALAND

ABSTRACT

STEWART, A. M., and W. G. HOPKINS. Consistency of swimming performance within and between competitions. Med. Sci. Sports Exerc., Vol. 32, No. 5, pp. 997–1001, 2000. Purpose: The consistency of performance between events impacts how athletes should specialize in events, how competitions should be structured, and how changes in performance affect an athlete’s placing in an event. We have therefore determined the consistency of swimming performance in events within and between two national-level competitions. Methods: We used mixed linear modeling to analyze official performance times of 149 male and 162 female swimmers at a junior national championship, and of 117 male and 104 female swimmers at an open national championship 20 d later. The events differed in stroke (backstroke, breaststroke, butterfly, freestyle, and individual medley) or distance (50–1500 m). Results: Swimmers were most consistent in their performance for the same event between the two competitions (typical variation between competitions, 1.4%; 95% likely range of true value, 1.3–1.5%). They were less consistent between distances of a given stroke within each competition (1.7%; 1.5–1.9%) and least consistent between strokes for a given distance (2.7%; 2.3–3.1%). Variation in performance between the longest continuous freestyle distances (400, 800, and 1500 m) in the open competition was half that between widely spaced freestyle distances (50, 200, and 800 m). Faster swimmers were more consistent (1.1%; 0.9–1.4%) for the same event between competitions than slower swimmers (1.5%; 1.3–1.9%). Conclusions: (a) Swimmers are stroke specialists rather than distance specialists; with the present set of events in competitions, they should concentrate training and competing on a particular stroke rather than a particular distance. (b) More swimmers would have a chance of winning a medal if events of a given stroke differed more widely in distance. (c) Factors that affect performance time by as little as 0.5% will affect the placing of a top junior swimmer. Key Words: COEFFICIENT OF VARIATION, RELIABILITY, REPRODUCIBILITY OF RESULTS, SWIMMING STROKES

In many sports athletes have the opportunity to compete in several events. In most cases, the events differ only in distance (e.g., running) or in technique (e.g., field athletics). Swimming is one of the few sports in which athletes compete in events differing both in distance and technique. Indeed, swimming competitions feature as many as 17 events drawn from five strokes (backstroke, breaststroke, butterfly, freestyle, and individual medley) and six distances (50, 100, 200, 400, 800, and 1500 m). Swimmers usually enter more than one event at a competition, but the consistency or reliability of their performance between events differing in distance or stroke is an issue researchers have not previously addressed. It has been our impression that swimmers tend to be consistently fast or slow in a given stroke over several distances, rather than consistently fast or slow over a given distance in several strokes. In the present study, we have addressed this issue by analyzing official competition results. Our findings could help swimmers make decisions about specializing in strokes or distances for training and competition. Our findings are also relevant to any consideration of the optimum distances in swimming competitions.

Talented swimmers usually enter several competitions in the course of a season, so it is also possible to estimate the reliability of performance in the same event between competitions. A recent analysis based on simulations of competitive events has shown that this reliability is the key factor in determining the extent to which a performance-enhancing strategy affects the chances of an athlete winning a medal (2). Briefly, an enhancement in performance has a substantial effect on medal prospects of a top athlete in an event only if the enhancement is at least 0.3, or more realistically 0.5, of the magnitude of the typical within-athlete variation in performance between events. Estimates of the variation in performance between events would therefore be useful to coaches and sport scientists who wish to enhance the performance of athletes. As yet, there are no published data on the reliability of competitive performance

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in any sport. In the present study, we have analyzed the results of two competitions to obtain estimates of this reliability for a group of talented young swimmers.

**METHODS**

**Subjects.** Competition organizers provided official performance times and ages for the 149 male and 162 female swimmers who competed at the New Zealand Junior National Championships, and for the 117 male and 104 female swimmers who competed at the New Zealand Open National Championships 20 d later. Ages of the male and female swimmers competing in the Junior Championships were, respectively, $15.1 \pm 1.3$ and $14.8 \pm 1.3$ yr (mean ± standard deviation); in the Open Nationals ages were, respectively, $17.9 \pm 2.7$ and $15.8 \pm 1.9$ yr. To gauge the caliber of the swimmers, we converted time in each event to a pace and expressed it as percent of the appropriate concurrent open-class world record pace.

**Consistency of performance.** We used the mixed linear modeling procedure (Proc Mixed) in the Statistical Analysis System (Version 6.12, SAS Institute, Cary, NC) to derive estimates of variability of performance between strokes, distances, and competitions. The dependent variable was 100 times the natural log of the time in an event; for small variations in performance (<5%), analyses of this transformed variable yield percent variations in performance directly (3,4). We performed separate analyses for female and male swimmers. For all analyses, we declared the identity of athletes as a random effect. We modeled the effect of random variation in an athlete’s performance between distances by declaring the interaction between the identities of athlete and distance as a random effect. We included the effect of random variation in performance between strokes in the same way. We first performed separate analyses for the two competitions (Table 1) using events with distances for which each stroke (other than individual medley) was represented (50, 100, and 200 m; backstroke, breaststroke, butterfly, and freestyle). We did not include individual medley, because its distances are only 200 and 400 m. We then analyzed only those athletes who entered the same event in both competitions; in this case, we also declared the interaction between athlete and competition to be random, to permit estimation of the effect of variation in performance between competitions (Table 2). The events were 100- and 200-m backstroke, breaststroke, butterfly, and freestyle. The code for the mixed procedure for the analysis that produced estimates of variation for male and female swimmers combined is as follows: proc mixed covtest nobound asycov; class athlete sex stroke distance comp; model time = sex*stroke*distance*comp; random athlete*stroke*athlete*distance *athlete*comp.

We investigated the effect of caliber of athlete on consistency of performance between strokes, distances, and competitions using the above model for separate analyses of faster and slower female and male athletes (Table 3). To sort the athletes into these two groups, we averaged each athlete’s performance (expressed as a percentage of world record) over all events, then for each sex we ranked the averages and split the athletes into the faster and slower groups at the median. We also performed an analysis for the effect of caliber of athlete on variation only between competitions by averaging each athlete’s performance in each of the 12 pairs of events that occurred in both competitions, ranking the average performance, splitting the athletes in each event at the median, then calculating the coefficient of variation between the competitions for each half of the field for each sex and for each event. The events were 100- and

**TABLE 1. Consistency of performance between strokes and between distances for Junior and Open National Championships.**

<table>
<thead>
<tr>
<th></th>
<th>Female CV (%)</th>
<th>95% CL (%)</th>
<th>Male CV (%)</th>
<th>95% CL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strokes</td>
<td>3.1</td>
<td>2.7-3.6</td>
<td>3.2</td>
<td>2.8-3.6</td>
</tr>
<tr>
<td>Distances</td>
<td>1.6</td>
<td>1.4-1.8</td>
<td>1.5</td>
<td>1.3-1.7</td>
</tr>
</tbody>
</table>

**TABLE 2. Consistency of performance between strokes, distances, and competitions, for swimmers who entered the same events in the Junior and Open National Championships.**

<table>
<thead>
<tr>
<th></th>
<th>Female CV (%)</th>
<th>95% CL (%)</th>
<th>Male CV (%)</th>
<th>95% CL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strokes</td>
<td>3.0</td>
<td>2.4-3.6</td>
<td>2.3</td>
<td>1.7-2.8</td>
</tr>
<tr>
<td>Distances</td>
<td>1.6</td>
<td>1.4-1.8</td>
<td>1.8</td>
<td>1.5-2.1</td>
</tr>
</tbody>
</table>

**TABLE 3. Consistency of performance between strokes, distances, and competitions, for faster and slower swimmers who entered the same events in the Junior and Open National Championships.**

<table>
<thead>
<tr>
<th></th>
<th>Female CV (%)</th>
<th>95% CL (%)</th>
<th>Male CV (%)</th>
<th>95% CL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strokes</td>
<td>2.7</td>
<td>2.0-3.3</td>
<td>2.1</td>
<td>1.4-2.6</td>
</tr>
<tr>
<td>Faster</td>
<td>2.9</td>
<td>1.3-3.9</td>
<td>1.8</td>
<td>1.1-2.3</td>
</tr>
<tr>
<td>Slower</td>
<td>1.4</td>
<td>1.2-1.7</td>
<td>1.7</td>
<td>1.2-2.0</td>
</tr>
<tr>
<td>Faster</td>
<td>1.7</td>
<td>0.9-2.2</td>
<td>1.9</td>
<td>1.3-2.4</td>
</tr>
<tr>
<td>Slower</td>
<td>1.3</td>
<td>1.1-1.5</td>
<td>1.2</td>
<td>0.9-1.4</td>
</tr>
<tr>
<td>Faster</td>
<td>1.7</td>
<td>1.4-1.9</td>
<td>1.3</td>
<td>1.0-1.6</td>
</tr>
<tr>
<td>Slower</td>
<td>1.2</td>
<td>1.0-1.5</td>
<td>1.0</td>
<td>0.8-1.4</td>
</tr>
<tr>
<td>Faster</td>
<td>1.5</td>
<td>1.3-2.0</td>
<td>1.6</td>
<td>1.2-2.2</td>
</tr>
<tr>
<td>Slower</td>
<td>1.2</td>
<td>1.0-1.5</td>
<td>1.0</td>
<td>0.8-1.4</td>
</tr>
</tbody>
</table>

CV, coefficient of variation; 95% CL, 95% confidence limits for the CV; numbers of swimmers — 81 female, 50 male; strokes — backstroke, breaststroke, butterfly, and freestyle; distances, 100 m, 200 m. * Derived by averaging CVs for the 12 events common to each competition, for the faster and slower half of athletes in each event.
200-m backstroke, breaststroke, butterfly, and freestyle, 200- and 400-m individual medley, 400-m freestyle, 800-m freestyle (female swimmers), and 1500-m freestyle (male swimmers). We derived a grand mean for the variation between competitions for each half of the field for each sex and for both sexes combined by averaging the variances for each event weighted by degrees of freedom. We derived confidence intervals for these grand means by assuming the events were independent, and by using the fact that the sampling distribution of a variance is a chi-squared distribution. We ensured that the confidence intervals were conservative (at least 95% intervals) by assuming the number of degrees of freedom equaled the number of athletes in each group.

We calculated consistency of performance as a coefficient of variation (CV) by adding the variance for a given random effect with the residual variance in the analysis and taking the square root. We then derived a standard error for this coefficient of variation by combining the asymptotic standard errors and covariance of the random effect and residual (obtained using the asycov option in the Proc Mixed statement). We then calculated the 95% confidence limits (CL) of the coefficient of variation as \( \pm 1.96 \) times the standard error.

**Statistics.** We have used means and standard deviations to represent the average and typical spread of values of variables. We have shown the precision of our estimates of coefficients of variation as 95% confidence limits (which define the likely range of the true value in the population from which we drew our sample).

Deriving confidence limits for most of the comparisons of pairs of coefficients of variation was beyond the resources of the authors, owing to the complexity of the measures. Instead, we have discussed qualitatively the likelihood of a difference between true values by referring to the extent of overlap of the confidence intervals. It is easy to show from first principles that two independent estimates of a normally distributed statistic with equal confidence intervals are significantly different at the 5% level if the overlap of their intervals is less than 0.29 \( (1 - \sqrt{2}/2) \) of the length of the interval. Although the coefficient of variation is not strictly a normally distributed statistic, with the large number of degrees of freedom in the present study, its distribution is approximately normal. Estimates of two coefficients of variation that include the same athletes are not independent, but by analogy with paired versus unpaired \( t \)-tests, dependence probably means that the two estimates are significantly different even if the overlap is somewhat greater than 0.29.

To discuss the observed magnitude of differences in coefficients of variation, we assumed arbitrarily that ratios of 1.5 and 2.0 represented moderate and large differences respectively.

**RESULTS**

The performances of male and female swimmers competing in the Junior National Championships were 81.2 \( \pm \) 4.2 and 82.6 \( \pm \) 3.5% of world records, respectively; in the Open Nationals, performances were 85.4 \( \pm \) 3.3 and 84.9 \( \pm \) 3.0% of world records. Table 1 shows the variation in performance that swimmers in the Junior Nationals and swimmers in the Open Nationals experienced between strokes of the same distance and between distances of the same stroke. The most obvious feature of these data is the substantially greater variation between strokes than between distances, for both competitions and for both sexes. Variation between the three distances in the Open Nationals was somewhat greater than between the two distances in the Junior Nationals. Reducing the number of strokes in the analysis to three, by deleting the data for the butterfly stroke, produced slight increases in the variation between strokes for both competitions (data not shown). Deleting the 50-m events from the analysis for Open Nationals (to make the distances the same as for the Junior Nationals) reduced the variations between distances to 1.8% (female swimmers) and 1.7% (male swimmers), which are only slightly greater than the variations between distances for the Junior Nationals.

Not included in the analyses in Table 1 are the data for individual medley and for freestyle events for distances of 400 m or more. There were two distances for individual medley (200 and 400 m) in both competitions, and two to three distances for freestyle (400, 800, and 1500 m), depending on sex and competition. The variations between distances for each of these strokes ranged from 0.8 to 1.9%, which is generally less than the average variation between distances shown in Table 1. We also analyzed 50-, 200- and 800-m freestyle events in the Open Nationals to determine the effect of widely different distances on consistency of performance. The variations between these distances were 2.1% (female swimmers) and 2.2% (male swimmers), which were substantially greater than the variations of 0.9% (female swimmers) and 1.3% (male swimmers) between the 400-, 800-, and 1500-m freestyle events in the Open Nationals.

Table 2 shows the analysis for the 81 female and 50 male swimmers who entered the same event or events in both competitions. Their performances, averaged over both competitions, was the same (84 \( \pm \) 3% of world record) for female and male swimmers. The variations between strokes and distances represent the same variations as in Table 1, except they are the averages for the two competitions for this subset. The magnitudes of these variations are mostly similar to those for the separate competitions, but the variation between strokes for this subset of males is substantially less than that of the full set. The analysis now includes between-competition variation, which represents the average of the usual test-retest variation or reliability for the eight events (four strokes, each with two distances). For female swimmers, this variation is slightly smaller than the variation between distances, whereas for male swimmers it is substantially smaller. When we analyzed the female and male swimmers together (taking into account any differences in performance), the variations were: between strokes, 2.7% (95% likely range, 2.3–3.1%); between distances, 1.7% (1.5–1.9%); and between competitions, 1.4% (1.3–1.5%).
Performances of the faster half of swimmers in the above subset of athletes were 87 ± 2% and 86 ± 2% of world record for female and male swimmers respectively; for the slower swimmers, performances were, respectively, 82 ± 2% and 82 ± 1% of world records. Variations in performance for these swimmers are shown in Table 3. With the exception of the performance of male swimmers between strokes, variability was less for the faster swimmers, and the effect was more marked for female swimmers. Differences in between-competition variation between faster and slower athletes were greater when we averaged between-competition variation across the 12 events common to each competition (Table 3). For female and male swimmers combined, the faster swimmers averaged 1.1% (0.9–1.4%) and the slower swimmers averaged 1.5% (1.3–1.9%).

DISCUSSION

Comparison of the coefficients of variation of performance between strokes and distances shows clearly that swimmers are more consistent between distances with the same stroke than between strokes with the same distance. These observations are consistent with the popular notion that the predictability of a swimmer’s performance is greater between events that differ only in distance than between events that differ only in stroke.

The greater variation between events differing in stroke is not due simply to the fact that there are more strokes (four) than distances (two for Junior Nationals and three for Senior Nationals), because dropping butterfly events from the analyses did not result in increased consistency. In contrast, the greater variation between events differing in distance for the Open Nationals than for the Junior Nationals appears to be due to inclusion of an extra distance (50 m) in the analysis for the Open Nationals. The obvious explanation for this effect is that swimmers who specialize in 50-m events perform less well over 200 m, whereas those who specialize in 200-m events perform less well over 50 m. Restricting the analysis to adjacent distances therefore results in increased consistency of performance.

A possible explanation for the greater consistency in events of the same stroke than in events of the same distance is that a different distance represents a physiological challenge, which different swimmers meet more easily than the technique challenge of a different stroke. Body build could help account for the difficulty swimmers have in adapting to different strokes, because there are substantial differences in the anthropometric characteristics of swimmers specializing in different strokes (1). Less consistency within a given distance than within a given stroke could also occur if coaches specialized in particular strokes, but our impression is that coaches specialize primarily in training for sprint, middle, or long distance rather than in training for a particular stroke.

The difference in consistency between strokes and distances means that swimmers in general will generally perform best over several distances in a particular stroke. If swimmers are interested in maximizing their success in competition, it follows that they should concentrate on those strokes during training, and enter events only in those strokes. Of course, at an early competitive stage swimmers need to experiment with the different strokes to find out the ones in which they are likely to succeed.

Our analysis of the variation between freestyle distances of 50, 200, and 800 m shows that limiting events to widely spaced distances can make the variation between distances closer to that between strokes. The physiological challenge of the different distances presumably then becomes similar to the technique challenge of the different strokes. Making these changes would introduce more fairness into championships, because there would be less tendency for the same swimmer to win more than one event within a given stroke. The public might also enjoy the spectacle of longer events. The 1500-m freestyle event (along with all the 100- and 400-m events) would need to be deleted from programs to make time for these events. Longer distances would provide a major physical challenge in the butterfly and individual medley and might therefore be impractical for these strokes.

We recognize that it would be difficult to persuade the governing bodies of swimming to make such substantial changes to the current format of competitive swimming.

For male swimmers, the variation in performance between distances was larger than the variation between competitions (Table 2). The difference was less marked for females, but the confidence intervals do not exclude the possibility that female swimmers were similar to male swimmers in respect of this difference. Thus, for male swimmers and probably also for female swimmers, a performance between different distances for the same stroke is somewhat less predictable than performance between competitions, even though the competitions were 20 d apart. Apparently, the physiological challenge of different distances in the same competition results in more variation in performance than any changes in physiology or technique that occur in the several weeks between competitions. With enough time between competitions, we would expect predictability to be less than between distances in the same competition.

The difference in consistency of faster and slower swimmers between competitions was more marked when the individual events were analyzed only for between-competition variation than when the analysis was combined with the between-stroke and between-distance analysis (Table 3). This difference arose almost certainly from the two ways in which the swimmers were split into faster and slower groups for these two analyses. In the analysis combined with strokes and distances, the split was on the basis of mean performance in all events, so the split would not have resulted in a clean separation into faster and slower groups for each event. In the analysis of individual events, each event was split cleanly into faster and slower groups, so any effect of swimming speed on consistency would be more marked.

On the basis of the limited overlap of the confidence intervals, our finding that the faster swimmers in each event were more consistent in their performance between competitions...
is probably true of swimmers generally. We have no data to help us explain the origin of this difference between the faster and slower swimmers, but several factors are likely. First, the faster swimmers may prepare for competitions more consistently and therefore compete more consistently. Second, the faster swimmers may have more competitive experience and may therefore select a pace closer to their optimum for a given stroke and distance. Finally, athletes who realize part way through an event that they are out of the running for a medal may reduce their pace a little, and the reduction may vary from race to race.

The coefficient of variation in performance between competitions is an important statistic for anyone interested in training or other strategies or factors that might affect performance. To change a top athlete’s chance of winning a medal, a strategy has to change a top athlete’s performance by an amount equivalent to at least 0.5 of the coefficient of variation; even smaller changes may be worthwhile for a team’s medal tally (2). The variation between competitions for the top junior swimmers in the present study was about 1%, so the change in performance time would need to be as little as ~0.5%.

The time to swim an event is made up of time to execute start, turns, and finish, and of course the time to swim between start, turns, and finish. Analysis of the time spent on each of these components by a particular swimmer, in combination with normative data for top swimmers, will enable a coach or sport scientist to determine where a gain in overall time of 0.5% or more is possible. For example, if the turns make up 20% of the overall time, a gain of 2.5% in turn time would be needed to improve overall time by 0.5%. A swimmer who is already performing turns better than most other swimmers might not be able to gain a further 2.5%, but instead could concentrate on increasing swimming speed by improving swimming technique or power output. In the case of power output, coaches and sport scientists need to be aware that gains in power need to be three times the gain in speed, owing to the fact that power is proportional to the cube of speed in sports where water or air provides the main resistance to forward motion (2). In the present example, 80% of the event time is made up of swimming, so a 0.5% gain in overall time would need a gain in swimming speed of 0.6%, which would be achieved with a gain in power of 1.9%. Strategies that are known to enhance output power by no more than, say, 1.5% in relevant studies using other modes of exercise would therefore have little effect on a swimmer’s chances of a medal.

CONCLUSIONS

Swimmers perform with least consistency between strokes of a given distance, with better consistency between distances of a given stroke, and at least for male swimmers, with most consistency in the same event between competitions. On the basis of these and other observations we suggest that swimmers should focus training and competing on a particular stroke and on one or two distances within that stroke. We also suggest that more swimmers could win medals if the distances of events for most strokes in a swimming competition were 50, 200, and 800 m. Finally, we show that gains of around half a percent in time are needed to affect a top junior swimmer’s chances of a medal. We advise coaches and sport scientists to analyze the components of the swimmer’s performance to determine how best to make such gains in performance.

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Address for correspondence: Will Hopkins, Department of Physiology, School of Medical Science, University of Otago, Box 913, Dunedin, New Zealand; E-mail: will.hopkins@otago.ac.nz.

REFERENCES