The Effect of Two Ten-Week Depth Jumping Routines On Vertical Jump Performance As It Relates to Leg Power

The Relative Stability of Maximal Aerobic Power in Elite Swimmers and its Relation to Training Performance

Energy Balance in Competitive Swimmers and Runners

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Abstract

In keeping with the original intent of the JSR, to act as a "researcher-to-coach" publication and to "educate coaches while informing them" the following bibliography has been compiled to serve the swimming community. These references have been assembled from a number of sources and although not a difficult task it was considerably labor intensive. Not all swimming related material is found within this listing. An attempt was made to include only those references judged by the authors to be information or research oriented and valuable to the swimming coach. It is hoped that this bibliography will be helpful by providing a quick and easy guide to information. If the response to this endeavor is positive it is our intent to continue these efforts in subsequent issues of JSR by assembling bibliographies for preceding and future years.

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The Effects of Two Ten-Week Depth Jumping Routines On Vertical Jump Performance As It Relates to Leg Power

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Abstract

This study compared the effects of a ten week three-day-per-week (3DW) and a ten week two-days-per-week (2DW) depth jumping (DJ) regimen upon vertical jump vs. performance. Seventy-five college aged students served as subjects for the study (N = 25 per group). A control group was incorporated into the study. Subjects only trained with DJ. Results indicate that the 2DW routine was significantly better than the 3DW at week four and week ten. There were no differences between the two experimental groups at week six and week eight. Both of the treatment groups were significantly better than the control group on the post test. Interestingly, the ten week training cycle did not produce performance plateaus for any group. Thus it would seem that VJ performance can be significantly influenced by a 2DW DJ routine as outlined in this study. However, it appears that a ten week training cycle may not be sufficiently long enough to produce optimum performance.

Key Words: Plyometrics, depth jumps, specificity, kinetic overload, power.

The ability to create leg power for quicker and more efficient starts and turns is critical to swimming success, particularly in the shorter events. Councilman (7) indicated that one of the three qualities necessary to be a good starter is power. In regard to turns, he reported that one of the common mistakes is the failure to push hard off the walls to develop maximum thrust. Yancher (20) stated that there should be an emphasis on developing leg power for improved starts and push off glides. One answer to the problem of leg power development appears to lie in plyometric training.

In recent years discourse and experimentation concerning the use of plyometrics as a training regimen for various sports has gained much popularity within the coaching community (1,6,13,17,18,21). In fact, O'Shea (14) claims that recent innovative training techniques like plyometrics may be responsible for the continued improvements observed in today's athletes. Plyometric training, and specifically depth jumping, has been credited with the development of explosive muscular contraction that is essential in numerous athletic events (9,15).

In theory, depth jumping enlists the myotatic reflex stimulated by kinetic overload upon the musculature. When a contracted muscle is stretched by an external force, such as dropping from a given height upon the hip, leg, and ankle extensors, mechanical work is absorbed by the muscle. This absorbed work becomes potential energy, that if exploited quickly, can increase the mechanical energy output during the subsequent shortening of the same musculature as in an upward vertical jump movement (3). Preliminary experiments by Cavagna and others (4) appear to have proved this hypothesis. This technique invokes the development of maximal strength, muscular coordination, and acceleration that is specific to most sport movements (8) and certainly to the starts and turns involved in competitive swimming.

Researchers in the USSR, and most especially Verhoshanski (16), originally called for a two-days-per week (2DW) training regimen while performing depth
jumps. However, recent literature has cited success with a three-days-per-week (3DW) regimen (1). Interestingly, no comparisons have been made between the two types of training regimens. In addition, past experimentation has usually incorporated an eight week training cycle (1,6,11) with a few exceptions advocating a sixteen week cycle (6).

Because of the inconsistency in the literature between the type and length of the jumping routines, this study was planned to answer two questions: (1) Is there a significant difference between a 2DW and a 3DW regimen, and (2) at what week does the subject reach optimum performance as measured by the vertical jump and reach test?

Method

Subjects

The subjects for this study were seventy-five male (N = 40) and female (N = 35) volunteer college-aged students at the University of Southern Mississippi (Table 1). Informed consent as outlined by the American College of Sports Medicine was obtained from all participants prior to initiation of activities. The subjects were divided into three intact groups: Group I trained with 40 depth jumps (DJ) three days per week, Group II trained with 40 DJ two days per week, and Group III was a control group that did not participate in DJ activities. As suggested as Clutch, et al (6) all subjects participating in the study had high school athletic experience and/or were active in the university intramural program before the training began. Consequently, it was felt that the subject population had an adequate athletic and preconditioning background. The subjects were asked to curtail all outside physical activity during the study.

Treatment

The subjects were blocked as intact classes and each class was randomly assigned to one of the three groups (N = 25). After an initial warmup procedure composed of flexibility exercises and jogging, the experimental groups were asked to execute 20 consecutive DJ's from a 0.75 meter (29 ½ inches) tower and 20 consecutive DJ's from a 1.10 meter (43 ½ inches) tower. The height of the towers was selected on the basis of Verhoshanski's work (16).

Depth jumps incorporate the training procedure of having the subject step off a tower of predetermined height, land upon a firm mat, and explode upward as rapidly as possible. The kinetic energy generated by this maneuver can as much as double the subject's body weight thus the overload principle comes into play. The subjects were familiarized and pre-trained in this DJ procedure as suggested by Chu (5). The subjects then entered the training cycle which lasted ten consecutive weeks due to semester time constraints.

A nonequivalent control group design was employed. Intact classes were used as groups with a pretest measure on VJ taken for each subject. The post-test VJ measures were taken at the end of weeks four, six, eight, and ten.

Test Administration

Performance in the VJ was pretested for each subject prior to the initiation of the training regimens. The Sargent Chalk Jump was selected as the performance test. Johnson and Nelson (10) report the reliability of this test of leg power at .93 with the validity coefficient being .78. The objectivity of the test is reported to be .93.

VJ was again tested, using the same Sargent Chalk Jump, at the end of four weeks and each successive two-week period until the subjects reached the end of the ten week training cycle.

Results

To analyze the data a 3 (exercise regimen) x 4 (weeks) repeated measures analysis of covariance was employed with the baseline vertical jump being used as the covariate. Since the study's design was a nonequivalent control group design and there were significant baseline differences among the groups (p < .001), analysis of covariance was the appropriate statistical analysis. Figure one summarizes the VJ baseline differences. Tests for homogeneity of variance (Fmax) and homogeneity of regression slopes (19) indicated the assumptions of analysis of covariance were met. The results revealed a significant covariate effect (p < .0001), a significant trials effect (p < .0001), and a significant interaction (p < .0001). Furthermore, the trials were decomposed into their orthogonal components to test for trends. These results indicated significant linear trend and a treatment

### Table 1 Subjects Descriptive Data

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<th>WT (KG)</th>
<th>PRE VJ (CM)</th>
<th>MALES</th>
<th>FEMALES</th>
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<td>47.34</td>
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a Standard deviation in parenthesis
interaction ($p < .0001$ and $p < .0001$, respectively). Figure one shows the unadjusted means while figure two shows the adjusted means.

Two questions were addressed in the study. The first was whether there was a difference in the 3DW workout regimen versus the 2DW regimen. As figure two apparently indicates, the answer depends on the week in which they are compared. Newman-Keuls analyses were used to pinpoint these differences. At week four the 2DW workout was superior to both the 3DW and the control groups while there was no significant difference between the three-day workout and the control group. Weeks six and eight produced identical results in that there was no significant difference between the two treatment groups, with both of them being superior to the control group. At week ten the two-day workout was significantly better than the three-day workout and the control group, and the three-day workout was better than the control group. In reviewing these results it should be noted that the two-day workout was consistently higher than the three-day workout even though the difference was not significant at weeks six and eight.

The second question addressed in the study was at what improvement plateaus and week an athlete can terminate the depth jumping. Once again by referring to figures one and two, one can see that the treatment groups improved at each week while control group showed relatively little improvement. The test for linear trend and subsequent Newman-Keuls analyses showed that the improvement was significant at each week for the treatment groups. For the control group there were possible differences between weeks four and ten. These differences may be attributed to learning (12).

By examining these results one can conclude that the subjects reached peak performances across trials, however, ten weeks of training may not be sufficient to reach optimum vertical jump performance.

**Discussion**

The results of this study seem to indicate that a ten-week two-days-per-week depth jumping routine is probably more effective than a ten-week three-days-per week program. It is important to note that even though all three groups significantly improved their VJ at the end of the ten weeks, the control group increased only 1.27 cm. This gain cannot be judged practical from an athletic performance standpoint. More important is the fact that both treatment groups gained an average of 7.62 cm on the VJ, with the 2 DW group being better than the 3 DW at the end of ten weeks.

A possible interpretation as to why the two-day DJ regimen, and consequently less work, is better than three-days-per week might be explained by the intensity of ef-
fort required by depth jumping. Veroshanski (16) has stated that due to the exacting biomechanical and physiological natures of depth jumping an athlete most probably has expended enough mechanical and muscular work as not to require a third day. It should be noted that only .70 cm separated the two experimental groups at the end of 10 weeks. This difference was significant from a statistical standpoint, but again from a practical standpoint the difference was perhaps not that great. These facts seem to highlight for the swimming coach that results can be achieved by a two-day program, saving time and energy for other types of training.

It is also interesting to note that the subjects had not plateaued before the ten-week training cycle ended. Bosco (2) has recommended an 18-month time period to adequately train the contractile and elastic properties of the muscles and the proprioceptive feedback mechanisms. This fact indicates that more research needs to be done to ascertain the optimum length of the training cycle. However, the results of this study seem to imprint that a ten-week two-day depth jumping routine can be beneficial to an athlete's vertical jump performance.

The practical application of this type of depth jumping, which incorporated no other type of weight training or sports conditioning program, is quite significant to coaches and swimmers. In effect, one way to quickly, simply, and inexpensively improve leg power, and subsequently starts and turns, is by adhering to the type of depth jumping program outlined in this study.

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The Relative Stability of Maximal Aerobic Power in Elite Swimmers and its Relation to Training Performance

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Abstract

The stability of maximal aerobic power ($\dot{V}O_{2\text{max}}$) within the intensive training period prior to international competition, and its relationship to training performance, was examined in a group of 11 male, and five female elite swimmers. Max $\dot{V}O_{2}$ was measured during a free-swimming test at four different times during the two month period. Swimming interval field tests were performed to assess changes in performance.

Intra-individual fluctuations in $\dot{V}O_{2\text{max}}$ values from the individual's mean score averaged from $-4.8\%$ to $+5.5\%$ over the four trials. Between the first and last test, there was no significant net change in either $\dot{V}O_{2\text{max}}$, or the performance variable. However, from the second test session to the third or fourth, there were small but significant improvements in $\dot{V}O_{2\text{max}}$ (5%) and performance (3%). No change from T3 to T4 was apparent in any of the tests. $\dot{V}O_{2\text{max}}$ scores for all four trials were slightly related to performance ($r = 0.36, p < 0.01$).

During intensive training, there may be small fluctuations in an individual's $\dot{V}O_{2\text{max}}$, however, overall changes across a two month intensive training period are slight. $\dot{V}O_{2\text{max}}$ is probably not a discriminant measure in the assessment of changes resulting in improved performance. $\dot{V}O_{2\text{max}}$ plays only a minor role as one of many contributing factors to the improvement of performance within the latter part of a training season, in elite athletes.

Introduction

Maximal aerobic power ($\dot{V}O_{2\text{max}}$) in competitive swimmers has been widely used as a criterion both in the evaluation of cardiovascular fitness (9), and as a predictor of performance in middle distance events (eg. 2, 3, 8).

Regular training usually results in an increase in $\dot{V}O_{2\text{max}}$ in normal, untrained individuals. In trained athletes, however, the results have not been consistent across studies (10, 11). Although swimmers spend a great deal of time performing interval-type training, which has been shown to produce more rapid, and larger gains in maximal aerobic power than other types of training, $\dot{V}O_{2\text{max}}$ in elite swimmers has been shown to remain constant from season to season, over a period of several years (6, 7). Improvements in racing times have continued over this same period. Over one season, increase in free-swimming $\dot{V}O_{2\text{max}}$ from four to eight percent have also been reported for elite swimmers (3, 10, 11). No measures of concurrent changes in performance were reported for the latter two studies. In the first paper (5), a significant (unspecified) correlation was found between $\dot{V}O_{2\text{max}}$ and performance in elite swimmers after nine months of training.

There is a lack of information regarding the changes in $\dot{V}O_{2\text{max}}$ that may take place during the swimming season. How these possible changes in $\dot{V}O_{2\text{max}}$ relate to changes or increases in swimming training performance has not been investigated. The purpose of this study was to monitor changes in $\dot{V}O_{2\text{max}}$ during the intensive training season prior to a major competition, and to determine the relationship between $\dot{V}O_{2\text{max}}$ and changes in swimming performance.

Methodology

The subjects were 11 male (mean age 17.5 $\pm$ 1.3 yrs, weight 72.5 $\pm$ 6.5 kg, and height 181 $\pm$ 6.1 cm) and five
female (mean age 16.6 ± 0.9 yrs, weight 58.9 ± 10.5, and height 170 ± 6.0 cm) swimmers who were all members of the National team of France. Each subject was tested four times, at the beginning of May (T1), in both early and late June (T2 and T3 respectively), and again early in July (T4). Each series of tests was completed within a four day period. The season training program included four weeks while at altitude (1800 m), which corresponded to the time between the first and second series' of tests. All subjects had performed the test procedures several times before the experiments reported here.

On the first day, free-swimming \( \dot{V}O_2 \text{max} \) tests were performed in a 50 m pool. Subjects swam at progressively increasing velocities (increments of 0.2 m/sec every four minutes), until the pace could not be maintained for at least two lengths of the pool. Pacer lights were used to ensure a constant velocity for each level, while the exact swimming speed was obtained by timing the middle forty meter segment of each length swum (1). Subjects swam their speciality stroke, which was either breast stroke or front crawl. Starting speed was set at 1.0 m/sec for front crawl swimmers, and 0.8 m/sec for the breast stalkers.

Duplicate gas collections were made during the last two minutes of each level. Expiratory volumes were collected in meteorological balloons which were placed in a cart that was moved along the deck beside the swimmer. Gas samples were drawn from the bags and analyzed for oxygen and carbon dioxide fractions with previously calibrated analyzers. \( \dot{V}O_2 \) values were calculated, and expressed in absolute terms (1/min), and after the last testing session, as a percentage of the highest result of the four obtained.

The day following each \( \dot{V}O_2 \text{max} \) test, a field test was performed according to each swimmer's best event. Distance swimmers performed a series of sixteen 50 m swims with a ten second rest interval between each swim. Two-hundred meter swimmers performed four 50 m swims, with 10 seconds rest between each, and 100 m sprinters swam two 50 m repeats, with ten seconds rest before the second swim. The total swimming time for all of the repetitions was used as the performance criterion. For T1 through T4, the performance variable was expressed as a percentage of the best result of the four testing sessions.

Separate repeated measures ANOVA procedures for performance and \( \dot{V}O_2 \text{max} \) scores (both absolute and as a percentage of the best result) were used to determine differences over time. Univariate F tests were used to determine the location of significant differences (p < 0.01). A Pearson product moment correlation was used to determine the relationship between \( \dot{V}O_2 \text{max} \) and performance, and changes in \( \dot{V}O_2 \text{max} \) and changes in performance from T1 to T2, from T2 to T3, and from T3 to T4.

Min. and Max. Variation (%) from Mean \( \dot{V}O_2 \text{max} \)

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</table>

Figure 1. Individual maximal deviations from mean \( \dot{V}O_2 \text{max} \).

Results

The means of the highest \( \dot{V}O_2 \text{max} \)'s measured for the males and females in the four month period were 4.97 l/min, and 3.69 l/min, respectively. Expressed in relative terms, the mean peak \( \dot{V}O_2 \) was, for men, 69.1 ml/kg/min, and for women, 59.2 ml/kg/min. Individual \( \dot{V}O_2 \text{max} \) values varied −4.8% to +5.5% from the mean \( \dot{V}O_2 \text{max} \) over T1 to T4 (Figure 1). The mean \( \dot{V}O_2 \text{max} \) for T1 and T4, were, for men, 4.6 ± 0.44 l/min and 4.77 ± 0.32 l/min respectively. The mean \( \dot{V}O_2 \text{max} \) for the women was 3.53 ± 0.29 l/min for T1, and 3.48 ± 0.31 l/min at T4 (Table 1).

Table 1. Mean group \( \dot{V}O_2 \text{max} \) (1 min⁻¹ ± S.D.) at four points within a season

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>4.60*</td>
<td>4.51</td>
<td>4.81</td>
<td>4.77</td>
</tr>
<tr>
<td>n = 11</td>
<td>± 0.44</td>
<td>0.37</td>
<td>0.37</td>
<td>0.32</td>
</tr>
<tr>
<td>Females</td>
<td>3.54</td>
<td>3.51</td>
<td>3.55</td>
<td>3.51</td>
</tr>
<tr>
<td>n = 5</td>
<td>± 0.25</td>
<td>0.32</td>
<td>0.41</td>
<td>0.28</td>
</tr>
<tr>
<td>All</td>
<td>4.27</td>
<td>4.19</td>
<td>4.41</td>
<td>4.38</td>
</tr>
<tr>
<td>n = 16</td>
<td>0.64</td>
<td>0.59</td>
<td>0.71</td>
<td>0.68</td>
</tr>
</tbody>
</table>

* 1 min⁻¹
± 1 S.D.
Table 2. Correlation coefficients between V̇O₂max scores for T1 to T4

<table>
<thead>
<tr>
<th>V̇O₂max</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>.88</td>
<td>.91</td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>.84</td>
<td>.82</td>
<td>.94</td>
</tr>
</tbody>
</table>

Correlations between maximal oxygen uptakes measured at each period of training are shown in Table 2. From one test to the next, the correlation coefficients are all equal to or greater than 0.91. Between the first test (T) and the third (T3), r = 0.88, and between T1 and the last test (T4), r = 0.84.

The mean group V̇O₂max and performance results, expressed as a percentage of the best result of all four trials, for T1 through T4, are listed in Table 3. There was no significant change between T1 and T4 in either group V̇O₂max or performance. However, there was a significant decline in the performance variable between T1 and T2, and also a concurrent, but non-significant decline in maxV̇O₂. Significant differences in both the maximal aerobic power, and in training performance, are apparent between T2 and T3, and between T2 and T4. The mean increase in V̇O₂max from T2 to T3 was 5.4%, and 4.5% from T2 to T4. There was no significant difference between T3 and T4 in either maxV̇O₂ or performance.

From T1 to T2 there was a significant decrease in the mean body mass of the group. This change after the training camp at altitude coincides with the decrease in the absolute group V̇O₂max.

There was a small, positive relationship between V̇O₂max and performance (r = 0.36, p < 0.01), and fluctuations in V̇O₂max were also slightly, but significantly related to changes in performance between subsequent testing periods (r = 0.37, p < 0.01).

Table 3. Mean group (n = 16) V̇O₂max and performance for T1 to T4

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>V̇O₂max</td>
<td>93.7</td>
<td>92.0</td>
<td>96.6</td>
<td>95.8</td>
</tr>
<tr>
<td>(Percent of best)</td>
<td>4.5</td>
<td>5.4</td>
<td>4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>Performance in training</td>
<td>98.5*</td>
<td>96.3*</td>
<td>98.8</td>
<td>99.3</td>
</tr>
<tr>
<td>(Percent of best)</td>
<td>2.0</td>
<td>1.8</td>
<td>1.5</td>
<td>1.1</td>
</tr>
</tbody>
</table>

(* sig. diff. p < 0.01)

Discussion

Only minimal changes were detected in the V̇O₂max of elite swimmers over the course of a season's training. Certainly, during the period at which the athletes were training at altitude, no positive adaptations occurred in either V̇O₂max or training performance. It is possible that this may be due to a reduction in the intensity of training necessitated by the environment, or related to the loss of weight in nearly all of the subjects during the same time.

During the peak intensive training period, V̇O₂max is not a discriminant variable in measuring improvements in conditioning or training performance. Improved performances are not as a consequence solely of increases in V̇O₂max, and therefore during the peaking for competition phase, other variables must be considered when planning training goals, or using physiological indices to monitor progress.

Perhaps what should be monitored are changes in the oxygen consumption at submaximal speeds, where the much larger capacity for change may allow for the detection of training effects (4).

Conclusions

The repeated measurement of maximal aerobic power during peak training is not a discriminating method for the prediction of improvements in swimming performance. The overall change in V̇O₂max in elite swimmers, over a span of 64 days, is minimal.

References

9. Lavoie, J.-M., and R.R. Montpetit. Applied physiology of swim-

ERRATUM

Editor's note: Unfortunately, due to a typesetting error that occurred on Pg 23, paragraph 4, line 3 of the article entitled: “Energy Balance in Competitive Swimmers and Runners” by K.T. Jang, et al., the following sentence was incorrect: “To effectively manage a swimmer with a weight problem, it would appear prudent to implement a calorie restricted diet.” The correct sentence should read: “To effectively manage a swimmer with a weight problem, it would appear prudent to have the swimmer first undergo dietary analysis prior to implementing a calorie restricted diet.” We apologize to the authors for this error and any misunderstanding which may have resulted.
Energy Balance in Competitive Swimmers and Runners

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D.L. Costill, Ph.D.
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J.A. Houmard, M.Sc.
J.B. Mitchell, M.A.
L.J. D'Acquisto, B.Sc.

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Muncie, Indiana 47306

Abstract

The purpose of this study was to examine the caloric intake and expenditure of male and female swimmers and runners to determine if there is a discrepancy that may explain the greater body fat observed in swimmers. Twenty collegiate swimmers (10 males and 10 females) and 20 collegiate runners (10 males and 10 females) recorded their food intake for a three day period. These records were subsequently analyzed for caloric intake and percent contribution of carbohydrate, fat, and protein. In a second part of the investigation, daily energy expenditures were estimated using subgroups of 5 male and 5 female swimmers and runners. Despite a large difference in body weight and body fat, the mean daily caloric intake was similar for the two groups (male swimmers: 3377 kcal·d⁻¹, male runners: 3463 kcal·d⁻¹, female swimmers: 2491 kcal·d⁻¹, female runners: 2037 kcal·d⁻¹). There was no difference in the caloric expenditure of male runners and swimmers for a 24 hour period, or when normalized for body weight (LBW). When normalized for total body weight, however, male runners expended more calories (53.3 kcal·kg⁻¹·d⁻¹) than the heavier swimmers (47.6 kcal·kg⁻¹·d⁻¹). Female swimmers expended more calories per day than female runners, 3027.6 ± 167.4 and 1946.8 ± 148.9 (P < 0.05), respectively. For the females, the differences were maintained when the expenditure was normalized for body weight and LBW. The results of this study suggest that the greater body fat found in swimmers compared to runners is not related to differences in caloric intake or energy expenditure.

Introduction

Endurance athletes are generally characterized as having below average levels of body fat. For example, the body fat in male distance runners has been reported to be less than 8% of body weight, well below the levels observed for normally active men (2, 17). It has been suggested that the reduced storage of fat is the result of increased energy expenditure induced by the energy demands of daily training. Surprisingly, not all endurance athletes are characterized by the same low body fat, despite equally high demands of training (5, 19). Many competitive swimmers, for example, expend approximately 1,000 to 4,000 kcal/day during training (~4000–20,000 m/d). This caloric output is the equivalent of running 10 to 40 miles per day. Despite these training demands, the body fat of swimmers is normally found to be 4–6% greater than that observed in age and ability matched groups of runners (8,15,19). The reasons for the disproportionate fat storage in swimmers is unclear. It is possible that swim training causes an increased appetite (7) or that swimmers, apart from training, maintain a relatively inactive lifestyle compared to runners. The purpose of this study was to examine the caloric intake and energy expenditure of swimmers and runners during their normal daily activity and training. The study was conducted in two parts: I) Analysis of caloric intake and nutritional content of the diet. II) Estimation of the daily energy expenditure of these two groups of athletes.
Methodology

Part I

Dietary Analysis: Ten male and 10 female collegiate swimmers and 10 male and 10 female collegiate runners participated in this part of the investigation. Each subject was informed of the nature of the study before giving written consent to participate. The subjects were taught to estimate food quantities and were shown how to properly complete the dietary records, which were obtained for 3 consecutive days. Caloric intake, percent carbohydrate, fat and protein were calculated using a commercially available computerized nutrition analysis program (The N: Nutritionist, Silverton, OR). Body fat was determined using the 7 site skinfold method described by Jackson and Pollock (9).

Part II

Estimation of Daily Energy Expenditure: Subgroups of 5 individuals were obtained from the four groups above for estimation of the daily energy expenditure. Daily activities were divided into five categories; supine, sitting, standing, walking, and exercise. To calculate the amount of time spent on various daily activities, an electronic watch was fastened to each subject’s right thigh for two days. The watch was connected to a mercury switch so it would operate when the subject was standing or walking and stop when he/she was sitting or supine. A pedometer was also attached to the subjects’ belt for both days to record walking mileage. An activity form was used to record the times the mercury watch was not being worn, e.g., sleeping, and to record the duration of exercise. The stride length setting on the pedometer (0.62 m) was determined from preliminary work. A walking speed of 3.52 km/h was used as the average walking speed for each subject.

Resting expired gas samples were collected for 5 min in the supine, sitting and standing positions. Subjects walked on the treadmill for 7 min at 3.52 km/h, expired gas was collected for the final 3 min. All samples were collected between 8:00 and 10:00 in the morning after a 12 h fast. Gas samples were analyzed using an Applied Electrochemistry S-3A O2 analyzer and Beckman LB-2 CO2 analyzers. The runners’ maximal oxygen consumption (VO2max) was measured during a stepwise incremental treadmill protocol using a semi-automated system for gas analysis (21). To estimate the caloric expenditure during a training session, runners were tested on the treadmill after 7 min of running at a set speed: 16 km/h for men and 13.6 km/h for women (~75% VO2max). The swimmers maximal oxygen consumption was calculated by collecting expired gases for 40 s following a maximal 365.8 m swim as previously described (14). Since the swimmers’ training incorporates a large amount of interval work at intensities ranging from 70-150% of maximal effort (unpublished), their caloric expenditure was assessed during a 365.8 m swim at a speed predetermined to require approximately 90% of VO2max. These values were used to estimate caloric expenditure during a training session.

Statistical Analysis: Differences between groups for caloric intake, caloric expenditure, and time allocation for each activity were tested for statistical significance with a student’s t-test. The level of significance was set at the 0.05 level. Values are reported as mean ± SE

Results

Physical Characteristics: A total of 40 athletes recorded their daily food intake in part I. As shown in Table 1, the mean body weight of male and female swimmers was significantly (p < 0.05) greater than the male and female runners, respectively. The mean percent body fat of the male and female swimmers was also significantly higher than male and female runners (Table 1). These differences were also present between the subgroups (n = 5) used in part II of this investigation. Mean body weights of the male swimmers and runners in part II were not significantly different, apparently because of considerable individual variation within the groups. (Table 1).

Table 1. Body weight (Kg) and percent body fat of male and female runners and swimmers.

<table>
<thead>
<tr>
<th></th>
<th>Swimmers</th>
<th>Runners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Part I Caloric Intake</td>
<td>Part II Energy Expenditure</td>
</tr>
<tr>
<td>Body weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (n = 10)</td>
<td>74.0</td>
<td>68.7</td>
</tr>
<tr>
<td>Female (n = 10)</td>
<td>66.1</td>
<td>51.6</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (n = 10)</td>
<td>12.4</td>
<td>6.6</td>
</tr>
<tr>
<td>Female (n = 10)</td>
<td>20.6</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Values are reported as Mean ± SE. * Indicates a significant difference between runners and swimmers (P < 0.05).
Part I

Caloric Intake: There was no significant difference in caloric intake between the male runners and swimmers or between female runners and swimmers. Male swimmers and runners consumed 3377 ± 213 kcal·d⁻¹ and 3463 ± 298 kcal·d⁻¹, respectively. The caloric intake of the female swimmers and runners was 2491 ± 264 kcal·d⁻¹ and 2037 ± 109 kcal·d⁻¹, respectively. There were also no significant differences between male or female swimmers and runners when the caloric intake was normalized for body weight (Table 2). Analysis of the three major nutrients (protein, carbohydrate, fat) showed that there was no difference between groups in the amount of each nutrient consumed.

Part II

Total Caloric Expenditure: Male swimmers and runners had an average daily caloric expenditure of 3495 ± 181 kcal and 3684 ± 114 kcal·d⁻¹, respectively. When this was normalized for body weight, a significant difference (P < 0.05) was revealed between swimmers and runners. Values expressed per kg LBW, however, showed no difference between groups (Table 5). The average daily caloric expenditure of female swimmers was significantly higher (3028 ± 167 kcal·d⁻¹) than female runners (1947 ± 149 kcal·d⁻¹). These values expressed per kg body weight and LBW were also significantly different (P < 0.05). These differences are more pronounced when expenditure was corrected for LBW since female swimmers possess more body fat (Table 5).

Caloric Expenditure During Daily Activities: There was no significant difference between male swimmers and runners in the time spent in each of five daily activities (sleeping, sitting, standing, walking, training) (Table 3). The

| Table 2. Average daily caloric intake (kcal, kcal·kg⁻¹) for a 3 day period. |
|---------------------------------|-----------|-----------|---------------|---------------|
|                                 | **Swimmers** | **Runners** |
| **Part I Caloric Intake Study** | Mean | SE | Mean | SE |
| Male (n = 10) |
| Intake | 3377.0 | 241.0 | 3463.0 | 298.0 |
| Intake/B.W. | 45.8 | 3.0 | 50.4 | 4.2 |
| Intake/L.B.W. | 52.0 | 2.9 | 53.8 | 4.4 |
| Female (n = 10) |
| Intake | 2491.0 | 834.0 | 2037.0 | 345.0 |
| Intake/B.W. | 38.0 | 4.2 | 39.9 | 2.5 |
| Intake/L.B.W. | 48.3 | 5.3 | 47.0 | 2.8 |
| **Part II Energy Expenditure Study** |
| Male (n = 5) |
| Intake | 3154.0 | 370.0 | 3155.0 | 328.0 |
| Intake/B.W. | 42.9 | 4.8 | 45.6 | 4.3 |
| Intake/L.B.W. | 49.0 | 4.7 | 49.0 | 4.4 |
| Female (n = 5) |
| Intake | 2339.0 | 353.0 | 1997.0 | 103.0 |
| Intake/B.W. | 34.9 | 6.9 | 40.4 | 2.3 |
| Intake/L.B.W. | 43.8 | 9.0 | 47.5 | 2.5 |

Values are reported as Mean ± SE. * Indicates significant difference between runners and swimmers (P < 0.05). B.W = Body weight, L.B.W = Lean Body weight

<table>
<thead>
<tr>
<th>Table 5. Daily Caloric expenditure (kcal, kcal·kg⁻¹).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Swimmers</strong></td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Male (n = 5)</td>
</tr>
<tr>
<td>Output</td>
</tr>
<tr>
<td>Output/B.W.</td>
</tr>
<tr>
<td>Output/L.B.W.</td>
</tr>
<tr>
<td>Female (n = 5)</td>
</tr>
<tr>
<td>Output</td>
</tr>
<tr>
<td>Output/B. W</td>
</tr>
<tr>
<td>Output/L. B. W</td>
</tr>
</tbody>
</table>

Values are reported as Mean ± SE. * Indicates significant difference between runners and swimmers (P < 0.05).
Table 4. Percentage of calories expended on daily activities

<table>
<thead>
<tr>
<th></th>
<th>Swimmers</th>
<th></th>
<th>Runners</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
<td>Mean</td>
<td>SE</td>
</tr>
<tr>
<td>Male (n = 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine</td>
<td>21.3</td>
<td>7.5</td>
<td>17.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Sitting</td>
<td>24.1</td>
<td>2.3</td>
<td>23.5</td>
<td>6.1</td>
</tr>
<tr>
<td>Standing</td>
<td>10.3</td>
<td>3.3</td>
<td>11.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Walking</td>
<td>11.7</td>
<td>4.9</td>
<td>10.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Exercise</td>
<td>32.5</td>
<td>8.3</td>
<td>37.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Female (n = 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine</td>
<td>22.3</td>
<td>5.6</td>
<td>25.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Sitting</td>
<td>22.4</td>
<td>6.5</td>
<td>27.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Standing</td>
<td>11.9</td>
<td>4.0</td>
<td>10.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Walking</td>
<td>18.9</td>
<td>6.4</td>
<td>14.0</td>
<td>5.3</td>
</tr>
<tr>
<td>Exercise</td>
<td>24.4</td>
<td>5.2</td>
<td>22.5</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Values are reported as Mean ± SE. * Indicates significant difference between runners and swimmers (P < 0.05)

female runners spent a significantly smaller amount of time walking compared to the female swimmers (107.0 min ± 11.6 and 156.6 min ± 17.3 respectively). However, when the amount of energy expended during each activity was expressed as a percentage of the total caloric expenditure, there was no significant difference between runners and swimmers of either sex (Table 4). There were no differences in percent of total caloric expenditure for each activity when normalized for body weight.

Caloric Balance: The mean caloric intake of the male swimmers, male runners and female swimmers was less than their caloric expenditure (figure 1). The female runners, on the other hand, appeared to be in caloric balance during the experimental period.

![Calorie Intake-Expenditure of Male and Female Swimmers and Runners](image)

Figure 1. Calorie intake and expenditure for subgroups (n = 5) of male and female swimmers and runners.

Discussion

Despite a large volume of training, swimmers in this study maintained a higher percent body fat than the runners. The average percentage of body fat in runners and swimmers was similar to those reported previously (8,13,15,16,17,19). It is unlikely that the difference in body fat was related to a difference in the ability levels of the athletes, since they were collegiate swimmers and runners from teams competing in the same conference.

A simple explanation for the difference in body fat between these two groups of athletes would be that the swimmers have a significantly higher caloric intake than runners. However, this does not appear to be the case since the male swimmers' and runners' caloric intake was nearly identical and the females differed only slightly (P > 0.5). The values for caloric intake of female runners and swimmers to the present study appear to be low for individuals with heavy training demands. These data are in agreement with those previously reported for female swimmers and runners (4,11,10,18). It has been suggested that animals that are swim-trained may consume a greater amount of food than treadmill trained animals (7). There is no indication from the present data that swim training may induce hyperphagia in collegiate swimmers.

Another possible but less likely explanation for the body fat difference would be that the swimmers, apart from training, maintain a less active lifestyle than the runners. The male swimmers and runners expended a similar amount of energy in a 24 h period. When these data were normalized for body weight, however, it appears that the male runners were more active than the swimmers and expended more calories in a 24 h period. This may be misleading because total body weight contains the less metabolically active adipose tissue. When normalized for LBW, however, male runners and male swimmers expended a similar amount of calories in 24 h. The female swimmers expended significantly more calories per day than the female runners regardless of how the data are expressed. Consequently, from the present data, neither caloric intake nor expenditure explain the body fat differences commonly observed between runners and swimmers.

The maintenance of high levels of body fat in swimmers is difficult to explain. Since the body's energy balance should determine the size of the body fat stores, a stable body composition and body weight suggests that the swimmers and runners are both in energy balance (12). Nevertheless, our study showed a caloric deficit in male and female swimmers and male runners, while the female runners appeared to be in energy balance. If a mathematical energy balance model is applied to the female swimmers, for example, assuming deficits occur only on training days, female swimmers should lose more than 1.6 kg of body fat per month. It is not likely that...
these athletes would have such a dramatic weight shift during their competitive season. A possible explanation for this discrepancy is provided by Yudkin and Chapell (22), who reported that food consumption may vary markedly from week to week even when body weight and activity level are maintained.

Previous research has demonstrated that swim training is relatively ineffective in reducing body fat stores. Clarke et al. (1), for example, reported that the body fat of children did not differ from controls after 7 months of competitive swim training. Similarly, female collegiate swimmers investigated by Katch and coworkers (10) actually increased their body fat after training for a full season. In contrast, we have measured a reduction in body fat in male and female swimmers over a competitive season (unpublished), and others have also reported slight decreases in body fat following arduous swim training (20). However, a consistent finding in reports that have compared swimmers of similar age and ability level is that swimmers maintain approximately 5% greater body fat than their running counterparts (8, 15, 19). The body fat differences observed in the present study were 5.8% and 5.4% for males and females, respectively. It should be noted that investigations that examine the effect of exercise training on body fat stores without controlling diet should be interpreted with caution.

The negative energy balance of the male and female swimmers (and male runners) in the present study suggests that an alternative explanation must be presented for the higher fat stores in swimmers. The physiologic and hormonal responses to exercise in water have been reported to be markedly different from those during dry land exercise (6, 12). It is possible that the hormonal milieu present during swimming exercise is favorable for a greater carbohydrate oxidation or lesser fat oxidation during exercise. In addition, the predominance of interval training incorporated into swimming training may also cause greater dependence on the body's carbohydrate stores. Another possibility is that the fat cell of the swimmer may be less sensitive to the effects of lipolytic hormones, thereby preventing fat release during exercise (3).

The practical implication of this investigation is that the higher fat levels of the swimmers do not appear to be a result of overeating or lack of activity. To effectively manage a swimmer with a weight problem, it would appear prudent to implement a calorie restricted diet. The swimmers in the present investigation appeared to be in a slightly negative energy balance. The coach who attempts to restrict caloric intake in these individuals may prevent the athlete from consuming the carbohydrate necessary to maintain a high level of training.

References


A quarterly publication for applied swimming science and research

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THE JOURNAL OF SWIMMING RESEARCH

— AUTHOR GUIDELINES —

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The JOURNAL OF SWIMMING RESEARCH is an official publication of the American Swimming Coaches Association. Manuscripts dealing with original investigations, comprehensive reviews, or brief reviews on the science of swimming and closely related topics, will be considered for publication. This journal is a researcher-to-coach publication. Information presented in the manuscript must be receiver-oriented. Authors submitting manuscripts to this journal must verify in writing that its contents represent original unpublished material that is not under consideration for publication elsewhere.

EDITORIAL STYLE: The author should submit three copies of a manuscript, typewritten and double-spaced with 1 1/2" margins on all edges. A short running title should be repeated at the top right corner of each page followed directly below by the page number. Authors should avoid all information which will identify human subjects.

English will be the language of this publication. As a general rule, only standardized abbreviations and symbols should be used. The first time an uncommon abbreviation appears it should be preceded by the full word or name it represents. The author is encouraged to refer to the Publication Manual of the American Psychological Association, 3rd edition, for editorial style concerning punctuation and abbreviations, construction of tables and figures, presentation of statistical symbols or mathematical equations, and use of standard units of measurement.

Manuscripts should contain the following elements placed in the following order:

1. TITLE PAGE. The title page should include the manuscript title, names of author(s) and their academic degree(s), name(s) and institution(s) where work is performed, an address and telephone number for editorial correspondence concerning the manuscript.

2. ABSTRACT. The abstract (200 words or less) should summarize the study's purpose, methodology, results, and conclusions. It should include a summary statement that provides some interpretation of the findings and their implications to the on-deck coaching and training of swimmers.

3. TEXT—The text should contain separate sections for:
   a. Introduction. This section should state the purpose, the rationale, and the essential related literature.
   b. Methodology. This section should include a clear description of the experimental subjects and their controls. The description of the methodology should provide enough detail for others to duplicate the study. References should be provided for established methods and statistical procedures should be supported with rationale.
   c. Findings. The findings presented in the text, tables, and figures should follow a logical and parallel sequence. The statistical significance of appropriate results should be acknowledged.
   d. Discussion. This section should emphasize the study's important and original aspects while avoiding a repeat of data presented in the findings section.
   e. Conclusion. The author should provide conclusions supported by their data. This section of the manuscript is of particular importance to the purpose of the journal. It should be of at least 300 words in length and provide in simple, laymen terms, an interpretation of findings and implications to the on-deck coaching and training of swimmers.

4. REFERENCES. The list of references should not exceed 20. They should be listed alphabetically by the last name of the author and typed double-spaced. The notation of the references in the body of the paper should be numbered in parentheses, one reference to a number. Journal articles should contain the last name of the first author, followed by initials, initials and last names of each co-author, title of article (first word only capitalized), name of journal (as abbreviated in the indexes published by the library of congress), volume, inclusive pages, and year. An example would be: Karlsson, J. A., Nordstrom, L. Jorfeldt and B. Saltin. Muscle lactate, ATP and CP levels during exercise and after physical training in man. J. Appl. Physiol. 33:199-201, 1972.

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