Esbjörnsson-Liljedahl, Mona, Carl Johan Sundberg, Barbara Norman, and Eva Jansson. Metabolic response in type I and type II muscle fibers during a 30-s cycle sprint in men and women. J. Appl. Physiol. 87(4): 1326–1332, 1999.—The acute metabolic response to sprint exercise was studied in 20 male and 19 female subjects. We hypothesized that the reduction of muscle glycogen content during sprint exercise would be greater in women than in men and that a possible gender difference in glycogen reduction would be greater in type II than in type I fibers. The latter hypothesis is based on the observation that the glycogen reduction is greater in type II than in type I fibers (15) and on the concept that women, to a lesser degree than men, may recruit/activate their muscle fibers (e.g., Ref. 4), especially type II fibers, during sprint exercise inasmuch as these fibers have a higher activation threshold than do type I fibers (18). To elucidate whether there are gender-related differences in the acute metabolic response to sprint exercise, the exercise-induced reduction of glycogen and high-energy phosphates was analyzed in type I and type II fibers in both men and women.

METHODS

Subjects. Twenty men and nineteen women (students at a college for sports and recreation instructors) volunteered for the study. None of the subjects was at an elite or competitive athletic level. They did participate in leisure-time sports (e.g., various ball games and jogging for the men and mainly calisthenics, aerobics, and jogging for the women). During class hours, all subjects took part in the same theoretical and practical classes (physical exercises). A questionnaire was used to estimate the physical activity level during leisure time. The subjects answered nine different questions, from which an activity index (minimum value 5.5 and maximum value 20.5) was calculated (22). As estimated by this questionnaire, the physical activity level did not differ between the genders (Table 1). Anthropometric data for the subjects are given in Table 1. Fat-free mass was estimated from skinfold measurements (triceps, biceps, and subscapula; Ref. 9).

All experiments were performed in the morning after an overnight fast. The subjects were asked not to perform any heavy exercise during the 24-h period preceding the experiment. Fourteen of nineteen female subjects were on oral contraceptives (11 subjects on 3-phase and 3 subjects on 1-phase pills). All subjects had regular menstrual cycles. To reduce the interindividual variation in hormone levels of the female subjects, all experiments were performed between day 12 and the last day of the menstrual cycle. The subjects were fully informed about the procedures and potential risks of the experiment and gave their consent to participate. The study was approved by the Ethics Committee of the Karolinska Institutet.

Experimental protocol. After familiarization, conducted at least 24 h before the experiment, a 30-s cycle sprint was performed (Wingate test; Ref. 1) on a mechanically braked cycle ergometer (Cardionics, Bredäng, Sweden). The subjects were instructed to pedal as fast as possible with an individual braking load set at 0.075 kp/kg body wt. A sensor-microprocessor assembly counted flywheel revolutions. The flywheel progression per pedal revolution was 6 m.

The acute metabolic response to sprint exercise was studied in 20 male and 19 female subjects. We hypothesized that the reduction of muscle glycogen content during sprint exercise would be greater in women than in men and that a potential gender difference in glycogen reduction would be greater in type II than in type I fibers. The latter hypothesis is based on the observation that the glycogen reduction is greater in type II than in type I fibers (15) and on the concept that women, to a lesser degree than men, may recruit/activate their muscle fibers (e.g., Ref. 4), especially type II fibers, during sprint exercise inasmuch as these fibers have a higher activation threshold than do type I fibers (18). To elucidate whether there are gender-related differences in the acute metabolic response to sprint exercise, the exercise-induced reduction of glycogen and high-energy phosphates was analyzed in type I and type II fibers in both men and women.

SPRINT EXERCISE leads to a major reduction in muscle ATP and phosphocreatine (PCr) content as well as a considerable reduction in glycogen content and a subsequent accumulation of lactate in both muscle and blood. These metabolic alterations seem to be fiber type specific. For instance, during sprint exercise the type II fibers lose much more ATP and glycogen (6, 15, 29) than do type I fibers. There are no studies, to our knowledge, in which gender-related differences in the fiber-type-specific metabolic response to sprint exercise have been addressed. It has been demonstrated, at the systemic level, that women have lower concentrations of blood lactate and plasma catecholamines than do men after sprint exercise (13, 26). In addition, glycolytic enzyme activities are lower in muscle from women than from men (10, 14, 31). Thus gender-related differences in metabolic response to sprint exercise, locally in the exercising muscle, are to be expected. We hypothesized that the reduction of muscle glycogen content during sprint exercise would be smaller in women than in men and that a potential gender difference in glycogen reduction would be greater in type II than in type I fibers. The latter hypothesis is based on the observation that the glycogen reduction is greater in type II than in type I fibers (15) and on the concept that women, to a lesser degree than men, may recruit/activate their muscle fibers (e.g., Ref. 4), especially type II fibers, during sprint exercise inasmuch as these fibers have a higher activation threshold than do type I fibers (18). To elucidate whether there are gender-related differences in the acute metabolic response to sprint exercise, the exercise-induced reduction of glycogen and high-energy phosphates was analyzed in type I and type II fibers in both men and women.

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Table 1. Anthropometric, morphologic, and power output data

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, yr</strong></td>
<td>25 (19–42)</td>
<td>23 (20–29)</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Body mass, kg</strong></td>
<td>75 (57–101)</td>
<td>65 (54–84)</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Fat-free mass, kg</strong></td>
<td>63 (51–82)</td>
<td>46 (36–54)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Height, cm</strong></td>
<td>178 (167–191)</td>
<td>167 (157–179)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Activity index</strong></td>
<td>16 (13–19)</td>
<td>15 (13–20)</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Fiber types, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>59 ± 10</td>
<td>62 ± 10</td>
<td>NS</td>
</tr>
<tr>
<td>Type IIA</td>
<td>30 ± 7</td>
<td>29 ± 8</td>
<td>NS</td>
</tr>
<tr>
<td>Type IIB</td>
<td>11 ± 9</td>
<td>9 ± 8</td>
<td>NS</td>
</tr>
<tr>
<td>Type IIC</td>
<td>1 ± 1</td>
<td>0 ± 1</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Relative area of fiber types, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>56 ± 12</td>
<td>66 ± 11</td>
<td>0.01</td>
</tr>
<tr>
<td>Type IIA</td>
<td>34 ± 10</td>
<td>27 ± 9</td>
<td>0.03</td>
</tr>
<tr>
<td>Type IIB</td>
<td>10 ± 9</td>
<td>7 ± 7</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Fiber areas, µm²</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>4,608 ± 909</td>
<td>4,195 ± 820</td>
<td>NS</td>
</tr>
<tr>
<td>Type IIA</td>
<td>5,503 ± 1,046</td>
<td>3,672 ± 622</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Type IIB</td>
<td>4,657 ± 669</td>
<td>3,194 ± 644</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Weighted mean fiber area, all fiber types (I, IIA, IIB)</strong></td>
<td>4,896 ± 735</td>
<td>3,968 ± 737</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Weighted mean fiber area, type II fibers (IIA, IIB)</strong></td>
<td>5,254 ± 893</td>
<td>3,563 ± 597</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Power output, W</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak power</td>
<td>860 ± 98</td>
<td>629 ± 91</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mean power</td>
<td>666 ± 75</td>
<td>467 ± 54</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are means ± SD with range in parentheses for 20 men and 19 women. NS, not significant. P values denote level of significance between men and women (t-test).

5-s periods was automatically printed. Peak power (i.e., the highest 5-s power) and mean power (the average power during the 30-s duration) were calculated. In addition, peak and mean power were adjusted for body mass and fat-free mass. This was done in a multiple-regression model, where peak or mean power was chosen as the dependent variable. Gender, together with body mass or fat-free mass, was chosen as independent variables (see also Statistics).

An indwelling catheter was inserted into an antecubital vein ~20 min before exercise. Two milliliters of blood were sampled ~2 min before exercise and subsequently at 3, 6, and 9 min after exercise (with the subjects in the supine position). Skeletal muscle biopsies were obtained from the vastus lateralis with the needle-biopsy technique (3) before and within 10 s of the cessation of exercise. Both biopsies were obtained from the same leg and skin incision, frozen in isopentane precooled with liquid nitrogen within a further 5 s, and stored at −70°C until later analysis.

Histochemical and morphological analyses. The biopsy taken before exercise was mounted in an embedding medium and analyzed histochemically for fiber types (I, IIA, IIB, and IIC) with a myofibrillar ATPase stain. Cross-sectional fiber area was measured morphologically by planimetry from an NADH-dehydrogenase stain. The relative number of the different fiber types (%type I, %type IIA, %type IIB, and %type IIC) and the relative area of the different fiber types (fiber type area) were calculated. In addition, mean type I, type IIA, and type IIB fiber areas; weighted mean fiber area of all fiber types combined; and weighted mean fiber area of the two type II fiber populations (IIA and IIB) were calculated. For more information about the histochemical and morphological analyses, see Jansson and Hedberg (22).

Single-muscle-fiber preparation procedures and analyses. After histochemical analysis of the preexercise biopsy, the rest of this biopsy and the one taken after exercise were freeze-dried, and ~100 single-fiber fragments were dissected from each biopsy. These were classified histochemically as fiber type I or II (12) and thereafter divided into separate pools of type I and type II. The mean weight of the pools was 40 µg (range 15–75 µg).

The fiber pools used for analysis of lactate, ATP, ADP, IMP, insulin, hypoxanthine, and PCr were extracted in 20–55 µl (depending on the weight of the pool) 0.4 M perchloric acid containing 0.06 M phenol red at 0°C. The pH of the extracts was brought to 8.2 by adding 1 M KOH. An HPLC technique, which has been described by Sellevold et al. (30), was used to determine the amounts of the metabolites in the fibers. The injection volume was 10 µl, and isotropic ion-pair reversed-phase assay (250 × 4.6-mm, 5-µm Nucleosil 120-C18 column) was used. The mobile phase used for separation consisted of 215 mM potassium dihydrogen phosphate (pH 5.6), containing 2.4 mM tetrabutylammonium hydrogen sulfate and 3.5% acetonitrile. ATP, ADP, IMP, insulin, and hypoxanthine were detected at 254 nm (model 440, Waters) and PCR at 206 nm (model 481, Waters) with two detectors connected in series.

The fiber pools used for glycogen analysis were digested by adding 20 µl of 1 M KOH, and then glycogen was extracted by vigorously mixing and warming the samples for 15 min at 50°C. The extracts were neutralized by addition of 0.25 M HCl. Amyloglucosidase was added to break down glycogen to glycosyl units (17), which were then measured by a fluorometric enzymatic method (24).

Blood analyses. Blood lactate was analyzed in neutralized perchloric acid extracts of whole blood by a fluorometric enzymatic method (24).

Methodological error. Methodological error (imprecision) for glycogen, ATP, ADP, IMP, and PCr was determined by analyzing extracts from two corresponding pools and was found to be between 5 and 8%.

Statistics. Unless otherwise stated, values in the text are means ± SD. The gender difference in exercise-induced blood lactate accumulation was tested by Student’s t-test for groups. The exercise-induced accumulation of blood lactate was defined as the change between the preexercise and the peak value. The peak value was defined as the highest of the 3-, 6-, or 9-min postexercise value. For the single-muscle-fiber variables (ATP, ADP, IMP, PCR, glycogen, and lactate), an ANOVA was performed to compare the exercise-induced responses between genders and in different fiber types. Gender and muscle fiber type (I or II) were chosen as independent variables and exercise-induced changes in various muscle metabolites as dependent variables. If a significant (P < 0.05) interaction effect was found between gender and fiber type, a contrast analysis was applied to identify the interaction (7). Student’s t-test was applied for paired observations or groups. The P values (all analyses) were accepted as statistically significant at P < 0.05.

Multiple-regression analyses were applied to analyze the influence of gender, body mass, and fat-free body mass (independent variables) on peak or mean power outputs (dependent variables). Multiple regression analyses were also used to analyze the influence of gender, glycogen content before exercise, and exercise-induced increase in IMP or decrease in ATP content (independent variables) on the exercise-induced decrease in glycogen content and exercise-induced increase in muscle lactate content or muscle lactate content after exercise (dependent variables).
RESULTS

Power output (Table 1). Absolute values of peak and mean power output were 27 and 30% lower, respectively, in women than in men. When peak and mean power output were adjusted for body mass, the women still presented lower peak (15% lower; \( P < 0.001 \)) and mean power outputs (18% lower; \( P < 0.001 \)) than did the men. When the power output was adjusted for fat-free body mass, there was a gender difference only for the mean power (8% lower in women than in men; \( P = 0.03 \)).

Fiber types and size (Table 1). There were no gender differences in the relative numbers of different fiber types. The relative area of type I fibers was smaller in women than in men. The cross-sectional area of type I fibers, on the other hand, was not statistically different between the genders. The cross-sectional area of type II A and type II B fibers and the weighted mean fiber area was 33, 31, and 20% smaller, respectively, in women than in men.

Blood lactate. The exercise-induced increase (peak value – preexercise value) in blood lactate concentration was 22% smaller in women than in men (Fig. 1).

Metabolites in muscle fiber-type comparisons (Table 2). Before exercise, there were no differences in ATP, ADP, IMP, or lactate content in the two fiber types. Glycogen content was \( \sim 1.2 \) times higher \( (P < 0.0001) \) and PCR was 1.1 times higher \( (P = 0.02) \) in type II than in type I fibers.

Sprint exercise induced a different metabolic response in type I than in type II fibers for most of the assessed metabolites. The reduction in ATP was \( \sim 3 \) times greater \( (P = 0.0001) \) in type II than in type I fibers, and the reduction in PCR content was 1.1 times greater \( (P = 0.003) \). The ADP content increased by 12% in type I, whereas there was no change in type II fibers. The accumulation of lactate was 1.4 times greater in type II than in type I fibers, and the accumulation of IMP was 2.5 times greater in type II \( (P = 0.0001) \). The exercise-induced glycogen reduction was approximately twofold greater in type II than in type I fibers in the women. In men, however, no difference in glycogen reduction was found between the two fiber types.

There were no detectable amounts of inosine or hypoxanthine in either type I or type II fibers before or after sprint exercise (detection limit was 0.05 mmol/kg dry muscle).

Metabolites in muscle gender comparison (Table 2, Fig. 2). Before exercise, no gender differences were found for the assessed substrates and metabolites in either type I or type II fibers.

Exercise-induced changes in ATP, ADP, IMP, and PCR content did not differ between men and women either in type I or type II fibers. Similarly, exercise-induced changes in glycogen and lactate in type II fibers did not differ between the genders. In type I fibers, however, the exercise-induced glycogen reduction was found to be 42% smaller in women than in men \( (gender; P < 0.02) \). The lactate content in type I fibers was 20% lower in women than men \( (gender; P = 0.01) \) after exercise. Furthermore, exercise-induced increase in lactate content in type I fibers tended to be smaller in women than men \( (gender; P < 0.09) \). After adjustment for the interindividual variation in the exercise-induced IMP accumulation in type I fibers (see DISCUSSION for further explanation), the gender differences in exercise-induced glycogen reduction and lactate content after exercise in type I fibers were further augmented \( (P < 0.01 \) and \( P < 0.0001 \), respectively). The gender difference in the exercise-induced increase in lactate content in type I fibers was significant at the level of \( P = 0.006 \) after adjustment for the interindividual variation in the type I exercise-induced IMP accumulation. In type II fibers the adjustment for exercise-induced accumulation of IMP did not reveal any gender-related difference in metabolic response in type II fibers.

Correlations. Exercise-induced glycogen reduction correlated with glycogen content before exercise in type I fibers \( (men, P = 0.003; women, P = 0.02) \) and in type II fibers \( (men, P = 0.02; and women, P = 0.004) \). However, in type I, but not in type II, fibers the regression lines were significantly different between men and women: at a given preexercise value of glycogen, the reduction in glycogen content was smaller in the women \( (P = 0.02) \).

DISCUSSION

Our hypothesis that the reduction in glycogen content in the type II fiber pool would be attenuated in women compared with men during sprint exercise was not confirmed: sprint exercise reduced the glycogen content in type II fibers similarly in both men and women by \( \sim 140 \) mmol/kg dry muscle. Similarly, the exercise-induced lactate accumulation and the lactate content after exercise did not differ between the genders in type II fibers \( (\sim 120 \) mmol/kg dry muscle). An extensive reduction of the ATP content in type II fibers to approximately one-half of the preexercise value occurred in both genders. The lack of a gender difference in exercise-induced metabolic changes in type II
fibers indicates that an attenuated recruitment/activation of type II fibers in women compared with men during sprint exercise is not likely.

The finding that the exercise-induced reduction in glycogen content in type I fibers was smaller in women than in men was unexpected. The smaller glycogen reduction in type I fibers in women was supported by the lower lactate content in the same fibers after exercise. A lower muscle lactate content in women than men after a 30-s cycle sprint has earlier been shown in biopsies that were not dissected into single fibers (20). Bell and Jacobs (2) also found a gender difference in glycogen degradation in women, as estimated from a histochemical glycogen staining, during repeated bouts of maximal isokinetic knee extensions. However, they found lower degradation in women in both fiber types. The discrepancy between the results of the present study and those of Bell and Jacobs may be related to the different exercise protocols or to the different techniques used for quantification of glycogen.

It is thought that the rate of glycogenolysis increases as a response to an increased ADP content and/or a decreased ATP content. An increased IMP content most likely reflects such a disturbed energy balance (e.g., Ref. 21). Therefore, the rate of glycogenolysis ought to relate to the increase in IMP content. In fact, a strong correlation was found between IMP and lactate accumulation during exercise in the present study (Figs. 3 and 4). However, for type I fibers, the regression lines describing the relationship between lactate and IMP accumulation were significantly different for the male and female subjects (different y-axis intercept). This means that, for a given increase in IMP, the women demonstrated a lower exercise-induced lactate content than did the men. This could be due to a limiting phosphorylase activity in women by either lower maximal velocity ($V_{\text{max}}$) or higher Michaelis constant ($K_m$) for the enzyme or lower concentrations of alternative stimulators, such as cAMP as discussed below. In type II fibers, however, no gender differences were found either before or after adjustment for exercise-induced accumulation of IMP.

The gender difference in the average rate of glycogenolysis over the 30-s exercise in type I fibers occurred

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**Table 2. Muscle substrate and metabolite content in type I and type II muscle fibers before and after 30-s sprint exercise**

<table>
<thead>
<tr>
<th></th>
<th>ATP</th>
<th>ADP</th>
<th>ATP/ADP</th>
<th>IMP</th>
<th>PCr</th>
<th>Glycogen</th>
<th>Lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preexercise type I</td>
<td>23±1</td>
<td>3.0±0.3</td>
<td>7.7±1</td>
<td>0±0</td>
<td>74±9</td>
<td>452±108</td>
<td>26±13</td>
</tr>
<tr>
<td>Postexercise type I</td>
<td>19±3</td>
<td>3.4±0.5</td>
<td>5.7±1</td>
<td>4.4±2</td>
<td>12±12</td>
<td>326±84</td>
<td>98±26</td>
</tr>
<tr>
<td>Preexercise type II</td>
<td>22±2</td>
<td>3.0±0.5</td>
<td>7.5±1</td>
<td>0±0</td>
<td>77±14</td>
<td>526±108</td>
<td>26±18</td>
</tr>
<tr>
<td>Postexercise type II</td>
<td>11±4</td>
<td>3.1±0.6</td>
<td>3.5±1</td>
<td>12.6±4</td>
<td>11±11</td>
<td>395±92</td>
<td>122±36</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preexercise type I</td>
<td>22±2</td>
<td>2.9±0.4</td>
<td>7.6±1</td>
<td>0±0</td>
<td>76±9</td>
<td>428±112</td>
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<td>Postexercise type I</td>
<td>18±3</td>
<td>3.3±0.7</td>
<td>5.5±1</td>
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<td>20±18</td>
<td>355±96</td>
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<td>Preexercise type II</td>
<td>22±2</td>
<td>2.9±0.6</td>
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<td>80±12</td>
<td>542±136</td>
<td>28±13</td>
</tr>
<tr>
<td>Postexercise type II</td>
<td>10±3</td>
<td>3.0±0.7</td>
<td>3.5±1</td>
<td>12.5±4</td>
<td>15±13</td>
<td>393±111</td>
<td>117±34</td>
</tr>
</tbody>
</table>

Values are means ± SD given in mmol/kg dry muscle for 20 men and 19 women. PCr, phosphocreatine. $P = 0.02$ for statistical level for gender difference of exercise-induced decrease in glycogen content in type I fibers. $P = 0.01$ for statistical level for gender difference of lactate content postexercise in type I fibers.

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**Fig. 2.** Changes in muscle ATP and IMP content induced by 30-s sprint exercise in type I and type II fibers in 20 men and 18 women. Nos. within figure are SDs.

**Fig. 3.** Relationship between 30-s sprint-exercise-induced lactate and IMP content in type I fibers in 20 men and 18 women. $P < 0.0001$ indicates that the 2 regression lines have different y-intercepts and that lactate content induced by sprint exercise was significantly lower in women than in men after adjustment for interindividual variation in sprint-exercise-induced increase in IMP content.
Despite a lack of gender difference in net ATP or PCR reduction or IMP accumulation in these fibers, this would indicate that type I fibers were activated/recruited to a similar degree in the two genders. The similar metabolic activation of the high-threshold type II fibers in both men and women, together with the principle of orderly recruitment of motor units (18), makes it unlikely that there would be a gender difference in the recruitment/activation of the low threshold type I fibers. Therefore, we do not think that the smaller glycogen reduction in type I fibers in women was due to a lower recruitment/activation of these fibers.

One possible explanation, however, for the lower rate of glycogenolysis in type I fibers in the women is the lower activity (lower $V_{\text{max}}$ or higher $K_{m}$) of enzymes limiting the anaerobic ATP-regenerating pathway in women. Women are known to have lower $V_{\text{max}}$ activities of lactate dehydrogenase, phosphofructokinase, and glycogen phosphorylase (see Ref. 10). However, we have found that the greatest gender difference in lactate dehydrogenase activity is found in type II fibers (M. Esbjörnsson-Liljedahl, C. Sylven, and E. Jansson, unpublished observations). Therefore, the lack of gender difference in the rate of glycogenolysis in type II fibers may argue against gender differences in glycolytic enzymes as the main explanation. The gender difference in activities of glycolytic or glycogenolytic enzymes may, to some extent, depend on the fact that women in general have a greater relative type I fiber area (10, 31). In turn, this may partly depend on the fact that women have a larger type I compared with type II fibers than do men. Whether this gender difference in the relative proportion of the different contractile proteins explains the gender difference in glycogenolytic rate of type I fibers is not known.

Another explanation could be that the gender difference in the rate of glycogenolysis in type I fibers was related to a smaller increase in plasma catecholamines during sprint exercise in women (5, 13, 26; M. Esbjörnsson-Liljedahl, K. Bodin, and E. Jansson, unpublished observations). Muscle glycogenolysis is known to be stimulated by intracellularly derived ADP or AMP, by Ca$^{2+}$, or by a $\beta$-receptor-induced increase in cAMP (e.g., Ref. 23). Glycogenolysis may depend more on $\beta$-receptor stimulation in type I than in type II fibers (28) because type I fibers have a threefold higher density of $\beta$-receptors than do type II fibers (25). This idea is supported by the finding that, during electrical stimulation of vastus lateralis, the glycogen depletion in type I fibers was more dependent on epinephrine than it was in type II fibers (16). During aerobic exercise, an attenuated reduction of muscle glycogen in women has also been demonstrated (27, 32). The cited studies presented data only on mixed muscle. Therefore, no data were available on fiber-type-specific gender differences in glycogen reduction. In the study by Tarnopolsky et al. (32), it was suggested that the attenuated glycogen reduction in the women was related to the lower plasma epinephrine levels in the women than in the men. This is in accordance with the explanation presented above. It has to be considered, however, that the average rate of glycogenolysis is ~100-fold higher during a 30-s sprint than during 90 min of aerobic exercise. Therefore, the metabolic responses to these two extremely different exercise protocols must be compared with caution.

Finally, a highly significant positive correlation between preexercise glycogen content and the glycogen reduction during sprint exercise was found in the present study, both in type I and type II fibers. In a multiple-regression analysis, the glycogen reduction in type I fibers was found to be explained by both the glycogen content before exercise and the gender. This means that the smaller glycogen reduction in type I fibers in women could in part, but not fully, be explained by their somewhat lower glycogen content before exercise.

In a previous study, it was shown that the adaptation to a 4-wk period of sprint training was gender related and fiber type specific: the cross-sectional area of type II fibers increased in the women but not in the men (11). The extensive reduction of ATP, PCR, and glycogen content in type II fibers found in the present study did not differ between men and women. Thus the findings of a greater hypertrophy of type II fibers in women than in men after sprint training may not be due to a gender difference in the metabolic response of type II fibers during sprint exercise. However, the findings of a gender difference in the metabolic response of type II fibers to sprint exercise in the present study may have implications for the adaptation to sprint training.

The smaller increase in blood lactate concentration after sprint exercise in women than in men seems not to be explained by a smaller reduction in glycogen content in the type II fibers in women. However, the smaller reduction of glycogen content in type I fibers in women may be a contributing factor to the smaller increase in blood lactate concentration in women. The observed gender difference in blood lactate accumulation may also be explained by a lower muscle mass in
women compared with that in men. However, the calculations below indicate that this is not the case. The leg muscle mass in the present study is estimated from the cross-sectional fiber areas, as measured in biopsies from each subject, and muscle length, which was approximated by the relative difference in body height. By this calculation the women had, on the average, 25% smaller leg muscle mass than did the men. Blood volume was not measured, but an estimation from height and weight showed that the women had an ~25% smaller blood volume than did the men (19). The resulting calculation of the gender difference in the relationship between the leg muscle mass and blood volume indicates that there is no gender difference in this relationship. Thus the muscle mass in relation to the blood volume did not seem to differ between men and women and thus could not explain the gender difference in blood lactate accumulation after sprint exercise.

The load chosen in the present study was 0.075 kp/kg body wt, as in our earlier sprint studies (10, 11). This load does not give an absolute maximal mean power, which is probably achieved at a load of ~0.09 kp/kg body wt for men and at a somewhat lower load for women (8). However, the curve describing the relationship between load and mean power is flat around the maximum point. Accordingly, the difference in the resulting mean power between 0.09 and 0.075 kp/kg body wt would be on average 5%, which is not very critical for the mean power (8). If anything, the gender difference may be underestimated at the load we have chosen. However, to make possible a comparison with our previous studies, we thought it was important to have the same load setting in the present study.

When attempting to identify gender-related differences in metabolic response during sprint exercise, it is important that the groups are comparable with respect to physical activity. In the present study, we selected physical education students at a boarding school. During the daytime, all subjects attended the same lectures, including both the theory and practice of different kinds of sports. According to the questionnaire-based activity index calculated in the present study, the level of leisure-time physical activity did not differ between the men and women. Thus the subjects in the present study can be considered well matched with respect to physical activity. Furthermore, all subjects of the present study can be considered well matched with respect to physical activity. In the present study, we selected different kinds of sports. According to the questionnaire-based activity index calculated in the present study, the level of leisure-time physical activity did not differ between the men and women. Thus the subjects in the present study can be considered well matched with respect to physical activity. Furthermore, all subjects of the present study can be considered well matched with respect to physical activity. In the present study, we selected different kinds of sports. According to the questionnaire-based activity index calculated in the present study, the level of leisure-time physical activity did not differ between the men and women. Thus the subjects in the present study can be considered well matched with respect to physical activity. Furthermore, all subjects of the present study can be considered well matched with respect to physical activity.

Conclusions. We found a fiber-type-specific and gender-related difference in the metabolic response to sprint exercise and an interaction between fiber type and gender in that response.

The smaller sprint-exercise-induced reduction in glycogen content, in type I fibers, in women than in men may contribute to the smaller accumulation of blood lactate in women after sprint exercise. The lack of gender difference in the reduction of ATP, PCr, and glycogen content in type II fibers may argue against an attenuated recruitment/activation of these fibers in women compared with in men during sprint exercise.

Knowledge about fiber-type-specific and gender-related difference in the metabolic response to sprint exercise may, besides being of basic scientific value, have implications for the design of training programs for men and women.

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