Dose-response study of GH effects on circulating IGF-I and IGFBP-3 levels in healthy young men and women


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Growth hormone (GH) is the major hormonal regulator of insulin-like growth factor I (IGF-I; see Ref. 10). In fact, serum IGF-I levels reflect the GH secretory status, being low in GH deficiency and elevated in acromegalic patients (4, 28). However, nutritional impairment leads to peripheral GH resistance, with low IGF-I levels in spite of elevated GH levels (10).

The evaluation of the IGF-I response to exogenous GH administration was proposed in the investigation of short stature (5, 8, 13, 25). However, the IGF-I generation test has never been defined in terms of GH dose, length of treatment, and timing in IGF-I assay as well as of normative values. Particularly, it is still unknown what is the lowest GH dose able to increase IGF-I levels in normal young subjects. As in GH-deficient adults, the increase in IGF-I levels during GH replacement was reported to be higher in males than in females (21), and whether the stimulatory effect of recombinant human GH (rhGH) on IGF-I levels is dependent on gender has to be verified in normal subjects. Interestingly, although basal IGF-I levels are similar in both sexes, spontaneous GH secretion over 24 h is clearly higher in young women than in men (20).

Hence, the aim of our study was to define the dose-response effect of a short-term treatment with different rhGH doses on IGF-I and insulin-like growth factor-binding protein (IGFBP)-3 levels in normal young adults of both sexes. The dose of 1.25 µg/kg rhGH did not modify IGF-I levels. The dose of 2.5 µg/kg rhGH significantly increased IGF-I levels in men (P < 0.05) but not in women, whereas the higher doses increased IGF-I levels in both sexes (P < 0.002). IGFBP-3 levels were not modified by 1.25 or 2.5 µg/kg rhGH in either sex. On the other hand, 5.0 µg/kg increased IGFBP-3 levels in men (P < 0.05) but not in women, whereas the higher doses increased IGFBP-3 levels similarly in both sexes (P < 0.02).

In conclusion, our results demonstrate that IGF-I and IGFBP-3 responses to rhGH are dose and sex dependent. However, IGFBP-3 is less sensitive than IGF-I to rhGH stimulation.

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and insulin were measured in duplicate by immunoradiometric assay (HGH-CTK IRMA and INSIK-5; Sorin, Saluggia, Italy). The sensitivity of the assay was 0.15 µg/l for GH and 2.5 µU/l for insulin. The inter- and intra-assay coefficients of variation were 4.9–6.5% and 1.5–2.9% for GH and 6.5–15.0% and 4.5–13.4% for insulin, respectively. Serum fT3 and fT4 were measured by RIA (Amerlex-MAB; Johnson & Johnson Clinical Diagnostic). The sensitivity of the assay was 0.5 pmol/l for fT3 and 0.6 pmol/l for fT4. The inter- and intra-assay coefficients of variation were 6.5–9.8% and 3.5–5.8% for fT3 and 5.0–15.0% and 3.7–6.5% for fT4, respectively. Plasma glucose was determined by the glucose oxidase colorimetric method (GLUCOFIX; Menarini Diagnostics, Firenze, Italy).

Data are expressed, either in absolute values or in incremental area under the curve, as means ± SE. The statistical analysis of the data was carried out by ANOVA and paired and unpaired Student’s t-test when appropriate.

**RESULTS**

Mean basal GH, IGF-I, and IGFBP-3 levels were 4.0 ± 0.8 µg/l, 27.7 ± 0.7 nmol/l, and 101.5 ± 3.5 nmol/l, respectively, and did not significantly differ among various testing sessions. GH levels were higher in women than in men (6.6 ± 2.1 vs. 0.5 ± 0.3 µg/l, P < 0.001), whereas no sex difference was shown in IGF-I and IGFBP-3 levels.

Placebo and the dose of 1.25 µg/kg rhGH failed to modify IGF-I levels at any time. On the other hand, the values significantly increased 12 h after the first administration of 2.5, 5.0, 10.0, and 20.0 µg/kg rhGH (IGF-I level at 12 h vs. basal: 28.9 ± 1.7 vs. 26.8 ± 1.9, 35.6 ± 2.1 vs. 30.1 ± 2.1, 35.5 ± 2.0 vs. 28.9 ± 1.6, and 36.1 ± 2.1 vs. 28.8 ± 1.8 nmol/l, respectively, P < 0.001). However, the increases in IGF-I levels observed after 5.0, 10.0, and 20.0 µg/kg rhGH were higher (P < 0.001) than that recorded after the 2.5 µg/kg rhGH dose (Fig. 1).

After the second, third, and fourth administration of 2.5, 5.0, 10.0, and 20.0 µg/kg rhGH, IGF-I levels further increased, showing a clear dose-response relationship (P < 0.001). Twenty-four hours after the last administration of each rhGH dose, IGF-I levels were decreased but still higher than basal levels (P < 0.007).

The dose of 1.25, 2.5, and 5.0 µg/kg rhGH failed to change IGFBP-3 levels at any time. IGFBP-3 levels were increased after the first administration of 20.0 µg/kg (112.0 ± 7.0 vs. 101.5 ± 7.0 nmol/l, P < 0.02) but not after 10.0 µg/kg rhGH. On the other hand, IGFBP-3 levels increased after the second, third, and fourth administration of both 10.0 (P < 0.01) and 20.0 µg/kg rhGH (P < 0.02–P < 0.001; Fig. 1).
Fig. 3. Dose-related effect of 4-day treatment with rhGH on IGF-I levels in 12 normal men (A) and 9 normal women (B; *P < 0.001 vs. placebo; ~P < 0.05 and + P < 0.004, males vs. females). \( \Delta \text{AUC} \), change in area under the curve.

Fig. 4. Dose-related effect of 4-day treatment with rhGH on IGFBP-3 levels in 12 normal men (A) and 9 normal women (B; *P < 0.05 vs. placebo; \( \phi \)P < 0.05, males vs. females).

Table 1. Insulin, glucose, fT₃, and fT₄ levels before and 84 h after the first administration of different rhGH doses

<table>
<thead>
<tr>
<th></th>
<th>Insulin, ( \mu\text{U} / \text{l} )</th>
<th>Glucose, mg/dl</th>
<th>fT₃, ng/dl</th>
<th>fT₄, ng/dl</th>
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<tbody>
<tr>
<td></td>
<td>Basal</td>
<td>84 h</td>
<td>Basal</td>
<td>84 h</td>
</tr>
<tr>
<td>Saline</td>
<td>10.6 ± 1.3</td>
<td>11.3 ± 1.5</td>
<td>80.6 ± 2.0</td>
<td>81.4 ± 1.8</td>
</tr>
<tr>
<td>rhGH doses, ( \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{day}^{-1} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td>9.5 ± 1.1</td>
<td>11.5 ± 1.5</td>
<td>82.3 ± 1.5</td>
<td>81.7 ± 2.5</td>
</tr>
<tr>
<td>2.5</td>
<td>10.5 ± 1.2</td>
<td>12.6 ± 1.8</td>
<td>83.5 ± 1.7</td>
<td>83.8 ± 2.1</td>
</tr>
<tr>
<td>5.0</td>
<td>13.0 ± 1.3</td>
<td>11.6 ± 0.8</td>
<td>82.6 ± 2.5</td>
<td>83.6 ± 2.1</td>
</tr>
<tr>
<td>10.0</td>
<td>11.5 ± 1.4</td>
<td>13.6 ± 2.5</td>
<td>79.5 ± 1.5</td>
<td>82.1 ± 2.1</td>
</tr>
<tr>
<td>20.0</td>
<td>13.1 ± 2.0</td>
<td>16.5 ± 2.4</td>
<td>82.5 ± 2.9</td>
<td>86.2 ± 2.5</td>
</tr>
</tbody>
</table>

Data are means ± SE. rhGH, recombinant human growth hormone; fT₃ and fT₄, free-3,5,3'-triiodothyronine and -thyroxine, respectively.
The ratio of IGF-I over IGFBP-3 (Fig. 2) was significantly increased during GH treatment with the dose of 5.0, 10.0, and 20.0 µg·kg\(^{-1}\)·day\(^{-1}\).

When the data, evaluated as changes in area under the curve (nmol·l\(^{-1}\)·24 h\(^{-1}\)) from baseline to 84 h, are examined dividing subjects by sex, the dose of 2.5 µg/kg rhGH significantly stimulated IGF-I levels in men (P < 0.05) but not in women. The higher doses increased IGF-I levels in both sexes (P < 0.001), but the IGF-I responses to the administration of 5.0, 10.0, and 20.0 µg/kg rhGH were lower in women than in men. However, this difference attained statistical significance only after the 5.0 and 20.0 µg/kg rhGH doses (P < 0.05 and 0.0004, respectively; Fig. 3). IGFBP-3 levels were not modified by 1.25 and 2.5 µg/kg rhGH in either sex. On the other hand, 5.0 µg/kg rhGH increased IGFBP-3 levels in men (P < 0.05) but not in women, whereas the higher rhGH doses similarly increased IGFBP-3 levels in both sexes (P < 0.01; Fig. 4).

All rhGH doses did not significantly modify fasting GH (data not reported), glucose, insulin, fT\(_3\), and fT\(_4\) levels (Table 1).

**DISCUSSION**

The results of our study in normal humans demonstrate that the lowest rhGH doses effective to induce an increase in IGF-I and IGFBP-3 levels are 2.5 and 5.0 µg/kg, respectively. Moreover, the IGF-I-releasing effect of various rhGH doses shows a clear dose-response relationship.

The stimulatory effects of rhGH on IGF-I and IGFBP-3 levels in normal subjects have been assessed before by Skjaerbaek and co-workers (26), who, however, used two rhGH doses markedly higher than those employed in our study.

Indeed, the minimal rhGH dose that we found able to increase IGF-I levels in normal subjects is much lower than that usually proposed for IGF-I generation tests (5, 8, 13). Moreover, the lowest effective dose of rhGH administered in our study is very close to the daily GH production rate estimated in normal young adults (29).

Thus testing with this dose is fundamental to verify the possible changes in hepatic GH sensitivity during life span and in various pathophysiological conditions, such as GH deficiency, obesity, malnutrition, catabolic states, Cushing's syndrome, and dilated cardiomyopathy.

On the other hand, the GH dose needed for replacement in severe GH-deficient adults still seems really low (3, 14, 15, 21).

Interestingly, our data demonstrate that the IGF-I and IGFBP-3 response to rhGH is dependent on gender; in fact, the lowest effective rhGH dose is higher in women than in men.

This evidence indicates that the peripheral GH sensitivity in men is higher than that in women. In agreement with our findings, it has been recently reported that, in GH-deficient adults, the IGF-I increase during GH chronic treatment was higher in men than in women (9, 14, 15, 21). The existence of a sex-dependent effect of rhGH on IGF-I synthesis and release is not surprising. In fact, although basal IGF-I levels are generally reported to be similar in both sexes (18, 23), spontaneous GH secretion over 24 h is higher in young women than in men (17, 20).

The GH-receptor number is probably gender independent, as indicated by evidence that GH-binding protein levels, a marker of GH-receptor status, in men and women are similar (2). On the other hand, there is evidence indicating that estradiol is able to reduce IGFBP-3 levels, likely impairing the postreceptor mechanisms underlying the stimulatory effect of GH on IGFBP-3 synthesis and release (22, 30).

Our findings also demonstrate that IGFBP-3 is less sensitive than IGF-I to rhGH stimulation, in agreement with previous results in GH-deficient adults (14, 15). Actually, IGFBP-3 synthesis and release depend on GH, but probably also on IGF-I (4, 11, 12, 27). This could also explain why the timing of the IGFBP-3 response is delayed with respect to that of IGF-I.

The evidence that IGFBP-3 is less sensitive than IGF-I to the stimulation by rhGH implies that the assay of IGF-I is more reliable than that of IGFBP-3 for investigating the GH secretory status and monitoring the adequacy of GH therapy in GH-deficient patients (19); notice also that IGF-I more than IGFBP-3 reflects the GH status in acromegalic patients (10, 28).

Indeed IGFBP-3 is also less sensitive than IGF-I to the physiological increase and decrease in GH secretion that occurs during puberty and aging, respectively (6, 7, 10).

Interestingly, an rhGH dose able to increase IGF-I but not IGFBP-3 levels also results in an increase in the IGF-I-to-IGFBP-3 ratio, which reflects an increase in the free, biologically active IGF-I (14, 16).

Finally, in spite of evidence that chronic rhGH treatment influences insulin and glucose levels as well as the thyroxine-to-3,5,3'-triiodothyronine conversion ratio both in normal and GH-deficient subjects (1, 15), we did not find any effect on these parameters. This could be due to the short-term treatment performed in our study. Alternatively, this evidence suggests that the previously reported effects were due to high rhGH doses.

In conclusion, the results of the present study in normal young adults demonstrate that the IGF-I and IGFBP-3 responses to rhGH are dose and gender dependent. Moreover, the minimum rhGH dose able to increase IGF-I and IGFBP-3 levels is unexpectedly low, and IGFBP-3 is less sensitive than IGF-I to rhGH stimulation.

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