Effect of different methods of active recovery after high-intensity exercise on intermittent exercise performance of soccer referees

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Abstract
This study aimed to examine the effect of different methods of active recovery (AR) after high-intensity exercise on exercise performance, determined with the Yo-Yo Intermittent Recovery Test level 2 (Yo-Yo IR2) in soccer referees. Using a crossover design, fourteen male soccer referees completed three trials. After resting for 10 min, participants ran approximately 495 meters (m) at 80% of maximum heart rate (HRmax) and, ran approximately 165 m at 90% of HRmax. This was followed by 15 min of passive recovery (control), 15 min of running at 130 beats/min (continuous AR), or 15 min of intermittent AR consisting of alternating 2.5 min intervals of passive recovery and running at 130 beats/min, repeated for 15 min (intermittent AR). Finally, participants performed the Yo-Yo IR2. Blood lactate and salivary cortisol concentrations were determined immediately after the rest, high-intensity exercise, recovery intervention and Yo-Yo IR2 periods. The Profile of Mood States (POMS) Questionnaire was measured after rest and Yo-Yo IR2. Yo-Yo IR2 performance was significantly higher in the intermittent AR trial than in the control trial. Blood lactate concentrations were significantly lower in the continuous and intermittent AR trials than in the control trial after the recovery intervention. No significant between-trial differences were observed in salivary cortisol concentrations. The fatigue score using the POMS increased significantly during the control and continuous AR trials, but not during the intermittent AR trial. In conclusion, AR with intermittent exercise after high-intensity exercise increases Yo-Yo IR2 performance compared to passive recovery.

Keywords: active recovery, intermittent exercise capacity, soccer referee

Introduction
Active recovery (AR) aims to maintain adequate blood flow after exercise and accelerate the removal of blood metabolites1). It also influences subsequent exercise performance1-3). When recovery time between periods of exercise is short (15 to 21 seconds [s]), active recovery (AR) is not an effective method to increase subsequent high-intensity exercise performance4). In contrast, AR is an effective method to increase subsequent high-intensity exercise performance via increased baseline oxygen uptake and aerobic energy production when periods of exercise are separated by 180-300 s intervals5). Therefore, duration of the recovery time is one of the important factors for considering the influence of AR.

Intermittent team sports, such as soccer, rugby league and union, handball, and basketball, are played over consecutive periods separated by a 10-20 min intermission. Passive recovery has been shown to reduce subsequent high-intensity exercise performance when the recovery time was within 10-20 min2,3). For example, according to Thiriet et al., passive recovery between repeated maximal periods of exercise significantly decreased the second exercise performance2). Monedero et al. have also observed that the passive recovery between repeated maximal cycling time trials decreased the second exercise performance by 3%3). In contrast, Hausswirth and Mujika have reported that AR with continuous exercise positively affects exercise performance when the interval between competitions is 30 min or less1). Moreover, Thiriet et al. have suggested that 20 min of AR with continuous exercise between repeated maximal exercise, up to 2 min in duration, is...
beneficial for maintaining exercise performance\textsuperscript{2}). While AR with continuous exercise appears to be beneficial for maintaining subsequent exercise performance, it is necessary to investigate the effect of other methods of AR on exercise performance for practical reasons. For example, AR with intermittent exercise can be performed alongside other specific ergogenic strategies during the rest period. However, to our knowledge, the effect of AR with intermittent exercise on exercise performance has been addressed in only one study\textsuperscript{11}. According to Monedero et al., AR with continuous exercise for 15 min did not influence the results of a subsequent 5-km cycling time trial, whereas AR with intermittent exercise improved such results\textsuperscript{11}. In the case of intermittent team sports, it is necessary to employ a performance test of intermittent protocol. The Yo-Yo Intermittent Recovery Test was utilized to investigate the intermittent exercise capacity of athletes who are performing intermittent team sports\textsuperscript{22}. The Yo-Yo Intermittent Recovery Test performance is related to the amount of high-intensity running, which is an important performance indicator for soccer players and referees\textsuperscript{7,8}. Previous studies have shown a positive correlation between the amount of high-intensity running and Yo-Yo Intermittent Recovery Test performance (player: $r = 0.71$, referee: $r = 0.75$)\textsuperscript{7,8}. Soccer referees are required to maintain an optimal position on the playing field to make accurate decisions. The highest percentage of accurate decisions is recorded when referees judge incidents from a distance of 11 to 15 m\textsuperscript{9}. For this reason, the mean distance covered by the main referee during a game is approximately 11 km\textsuperscript{6,10} and the amount of high-intensity running (i.e., at a speed exceeding 15 km/h) is approximately 800 m\textsuperscript{11}. These values are similar to those of soccer players (mean distance covered: 11 km, the amount of high-intensity running: 900 m)\textsuperscript{23}. Therefore, physical demands and exercise intensity during a game may be similar in soccer referees and soccer players. However, studies on soccer referees are less frequent than those on soccer players.

Therefore, this study aimed to examine the effect of different AR methods after high-intensity periods of exercise on intermittent exercise performance determined with the Yo-Yo Intermittent Recovery Test in soccer referees. We hypothesized that AR with intermittent exercise increases Yo-Yo intermittent recovery test performance.

**Materials and Methods**

**Subjects.** Fourteen male referees who trained for more than 4 days per week participated in this study. All the referees had second (n = 3) or third class (n = 11) official licenses from the Japan Football Association. The age, height, and body mass were 21.5 ± 0.7 years, 173.5 ± 5.7 cm, and 66.6 ± 6.7 kg (mean ± standard division [SD]), respectively. The referees were informed on the experimental procedures and possible discomfort associated with participating in the study prior to providing written consent. The study was approved by the Ethics Committee of the Tokyo Gakugei University (Approval number: 103).

**Procedure.** Using a randomized crossover design, participants completed three trials (control [i.e., passive recovery], AR with continuous exercise (continuous AR), and AR with intermittent exercise (intermittent AR). All trials were separated by at least 5 days. At least 5 days prior to the first trial, participants performed the Yo-Yo Intermittent Recovery Test level 2 (Yo-Yo IR2) to familiarize themselves with the experiment. The trials started at the same time (i.e., between 7 and 8 am) to account for chronobiological rhythms. Participants were asked not to alter their regular training, diet, and lifestyle on the day before each trial. Participants recorded all food and liquids consumed the day before each trial. The dietary intake for the first trial was replicated in subsequent trials, ensuring that meals were standardized across trials.

The study protocol is shown in Fig. 1. After fasting for 8 hours overnight, except for water intake, participants rested on a chair for 10 min. Then, participants performed high-intensity exercise. This high-intensity exercise was used in the previous study regarding the effect of different recovery methods on blood lactate concentration\textsuperscript{24}. Participants made a round trip diagonally between the corners of the penalty area 3 times (i.e., approximately 495 m) by running at 80% of maximum heart rate (HRmax) (i.e., 220 - age), followed by a single identical round trip (i.e., approximately 165 m) at 90% of HRmax. Blood and saliva samples were then collected for one minute. Then, participants either rested on a chair for 15 min (control), ran at intensity of 130 beats/min for 15 min (continuous AR), or alternately rested on a chair for 2.5 min followed by running at intensity of 130 beats/min for 2.5 min for a total of 15 min (intermittent AR). The intensity and duration of AR were as in the previous study\textsuperscript{3}. Blood and saliva samples were then collected again for one minute. Finally, participants performed the Yo-Yo IR2. Participants ran to the 20-m marker and back to the start, which had to be completed by the time of the second signal. Then, participants had a 10 s break, during which they walked around the 5-m marker. If participants arrived at the start marker before the next signal, they waited there until the next signal. If participants failed twice to reach the start marker before the second signal, the test was terminated.

The present study has noted similar weather conditions among three trials. The wet-bulb globe temperature was 20.3 ± 6.9 °C (mean ± SD).

**Measurements.** HR was recorded throughout the trial using a wireless HR monitor (Polar RS800, Polar Electro, Kempele, Finland) at 5-s intervals. Mean HR was calculated during the 10-min rest, high-intensity exercise, recovery interventions, and Yo-Yo IR2 periods. Maximal HR was calculated during the Yo-Yo IR2 period.
Blood lactate concentration was determined by using a lactate analyzer (Arkray, Lactate Pro 2, Japan) after the 10-min rest (pre), high-intensity exercise (post1), recovery interventions (post2), and Yo-Yo IR2 periods (post3).

Salivary cortisol concentration was used as an indicator of objective fatigue. Salivary samples were collected by drooling method for one minute at the pre, post1, post2, and post3. Salivary samples were stored at -80 °C until analysis. Salivary cortisol concentration was analyzed using a kit from Immunospec Corporation (Cortisol Saliva, EIA Kit).

The Profile of Mood States (POMS) Questionnaire was used to evaluate subjective stress using the subscales tension-anxiety, depression, anger-hostility, vigor, fatigue, and confusion. Total mood disturbance was calculated by using the following formula: tension-anxiety + depression + anger-hostility + fatigue + confusion – vigor. The POMS questionnaire was administered at pre and post3.

**Statistical analysis.** Unless otherwise stated, all values are shown as mean ± SE. Statistics were computed using the SPSS software (version 18.0, SPSS Japan Inc., Japan). Yo-Yo IR2 performance, HRmax and percentage decrement in blood lactate concentration from post1 to post2 were compared by using repeated measures one-factor analysis of variance. When a significant interaction was detected, values were subsequently analyzed using the Bonferroni multiple comparisons test. Statistical significance was set at P < 0.05.

**Results**

**Yo-Yo Intermittent Recovery Test Level 2 performance.**
Yo-Yo IR2 performance is shown in Fig. 2. Yo-Yo IR2 performance in the intermittent AR trial was higher than in the control trial (848.2 ± 42.1 vs. 763.7 ± 43.5 m; P = 0.002).

**Heart rate.** The mean HRs during the 10-min rest, high-intensity exercise, recovery intervention, and Yo-Yo IR2 are shown in Table 1. There were main effects of trial (P < 0.001), time (P < 0.001), and trial × time interaction (P < 0.001) on mean HR. Subsequent post-hoc tests revealed significant between-trial differences in mean HR during the recovery intervention (P < 0.001) and Yo-Yo IR2 (P = 0.005) periods. The mean HR during the recovery intervention period in the control trial was lower than in the continuous (P < 0.001) and intermittent AR trials (P < 0.001). Further, the mean HR during the recovery intervention in the intermittent AR trial was lower than in the continuous AR trial (P < 0.001). The mean HR during Yo-Yo IR2 in the control trial was lower than in the continuous (P = 0.046) and intermittent AR trials (P = 0.026). There was no significant difference between the continuous and intermittent AR trials in mean HR during Yo-Yo IR2. The maximal HR during Yo-Yo IR2 in the control, continuous, and intermittent AR trials were 183 ± 2, 186 ± 2, and 186 ± 2 beats/min, respectively. There was a main effect of trial (P = 0.003) on maximal HR. The maximal HR in the control trial was lower than in the continuous (P = 0.017) and intermittent AR trials (P = 0.035).
was no significant difference in maximal HR between the continuous and intermittent AR trials.

**Blood lactate concentration.** Blood lactate concentrations at each measurement point are shown in Fig. 3. One participant’s blood lactate concentration at post1 in the control trial was substantially higher (i.e., 18.3 mmol/L; mean of other 13 participants: 9.7 ± 0.9 mmol/L) than in the intermittent (i.e., 13.0 mmol/L; mean of other 13 participants: 8.5 ± 0.8 mmol/L) and continuous (i.e., 14.5 mmol/L; mean of other 13 participants: 8.1 ± 0.8 mmol/L) AR trials, despite a similar mean HR observed in the three trials during high-intensity exercise. Thus, this participant was not included in the analyses of blood lactate concentrations. There were main effects of trial (P < 0.001), time (P < 0.001), and trial × time interaction (P < 0.001) on blood lactate concentration. Subsequent post-hoc tests revealed significant between-trial differences in blood lactate concentration at post2 (P < 0.001). Blood lactate concentrations at post2 in the control trial were higher than in the continuous (P < 0.001) and intermittent AR trials (P = 0.001). There were no significant between-trial differences in blood lactate concentrations at pre, post1, and post3. There were significant between-trial differences in the percentage decrement of blood lactate concentration from post1 to post2 (P < 0.001). The percentage decrements of blood lactate concentration from post1 to post2 in the continuous and intermittent AR trials were higher than in the control trial (control: 38.4 ± 7.0, continuous AR: 68.5 ± 8.3, intermittent AR: 64.8 ± 4.0%, P = 0.001, 0.013; Fig. 4). There was no significant difference between the continuous and intermittent AR trials in percentage decrement of blood lactate concentrations from post1 to post2.
**Fig. 3** Blood lactate concentrations at each measurement point among three trials. Means were compared by using two-factor analysis of variance. Control: a passive recovery trial. Continuous AR: an active recovery with continuous exercise trial. Intermittent AR: an active recovery with intermittent exercise trial. (n = 13, mean ± standard error).

a main effect of trial; P < 0.001, a main effect of time; P < 0.001, trial × time interaction; P < 0.001

* Significantly different between the control and the continuous AR trials (P < 0.05)
† Significantly different between the control and the intermittent AR trials (P < 0.05)

**Fig. 4** Percentage decrement (i.e. decrement from post 1) in blood lactate concentrations after each recovery period (i.e. post 2). Means were compared by using one-factor analysis of variance for the main effect of trial followed by a Bonferroni multiple comparisons test. Control: a passive recovery trial. Continuous AR: an active recovery with continuous exercise trial. Intermittent AR: an active recovery with intermittent exercise trial. (n = 13, mean ± standard error).

a main effect of trial; P < 0.001
* Significantly different from the control trial. (P < 0.05)

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**Salivary cortisol concentration.** Salivary cortisol concentrations at each measurement point are shown in Fig. 5. There were no main effects of trial, time, and trial × time interaction on salivary cortisol concentrations.

**Profile of Mood States Questionnaire.** Tension-anxiety, depression, anger-hostility, vigor, fatigue, confusion, and total mood disturbance scores of the POMS Questionnaire are shown in Table 2. There were no main effects of trial, time, and trial × time interaction on tension-anxiety, depression, anger-hostility, vigor, confusion, and total mood disturbance scores. There were main effect of time (P = 0.002) and trial × time interaction (P = 0.042) on fatigue score. There was no main effect of trial on fatigue score. Subsequent post-hoc tests revealed significant differences between pre and post3 in fatigue score for the control (P = 0.009) and continuous AR (P < 0.001) trials, but not for the intermittent AR trial.

**Discussion**

This study examined the effect of different AR methods after high-intensity exercise on intermittent exercise performance, determined by Yo-Yo IR2, in soccer referees.
Fig. 5  Salivary cortisol concentrations at each measurement point among three trials. Means were compared by using two-factor analysis of variance. Control: a passive recovery trial. Continuous AR: an active recovery with continuous exercise trial. Intermittent AR: an active recovery with intermittent exercise trial. (n=14, mean ± standard error).

Table 2. The Profile of Mood States (POMS) score at each measurement point among three trials

<table>
<thead>
<tr>
<th>Trials</th>
<th>Control</th>
<th>Continuous AR</th>
<th>Intermittent AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension-Anxiety</td>
<td>pre 47.4 ± 2.1</td>
<td>47.7 ± 1.8</td>
<td>46.6 ± 1.7</td>
</tr>
<tr>
<td></td>
<td>post 3 48.4 ± 1.8</td>
<td>48.6 ± 1.7</td>
<td>47.9 ± 2.0</td>
</tr>
<tr>
<td>Depression</td>
<td>pre 50.6 ± 2.8</td>
<td>49.5 ± 1.6</td>
<td>49.4 ± 2.1</td>
</tr>
<tr>
<td></td>
<td>post 3 49.3 ± 2.2</td>
<td>48.6 ± 2.0</td>
<td>47.7 ± 1.9</td>
</tr>
<tr>
<td>Anger-Hostility</td>
<td>pre 47.6 ± 2.4</td>
<td>48.6 ± 2.1</td>
<td>46.9 ± 2.1</td>
</tr>
<tr>
<td></td>
<td>post 3 45.1 ± 2.6</td>
<td>46.4 ± 2.0</td>
<td>45.9 ± 2.1</td>
</tr>
<tr>
<td>Vigor</td>
<td>pre 47.2 ± 2.9</td>
<td>48.6 ± 2.7</td>
<td>46.6 ± 2.3</td>
</tr>
<tr>
<td></td>
<td>post 3 46.0 ± 3.2</td>
<td>48.6 ± 3.1</td>
<td>46.3 ± 2.4</td>
</tr>
<tr>
<td>Fatigue</td>
<td>pre 52.0 ± 2.3</td>
<td>50.4 ± 2.1</td>
<td>52.6 ± 3.4</td>
</tr>
<tr>
<td></td>
<td>post 3 56.5 ± 2.3</td>
<td>56.6 ± 2.4</td>
<td>54.6 ± 3.1</td>
</tr>
<tr>
<td>Confusion</td>
<td>pre 48.6 ± 3.6</td>
<td>48.5 ± 1.8</td>
<td>48.1 ± 12.6</td>
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<tr>
<td></td>
<td>post 3 47.9 ± 3.3</td>
<td>48.5 ± 1.5</td>
<td>45.9 ± 11.5</td>
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<tr>
<td>Total Mood</td>
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<td>39.4 ± 7.4</td>
<td>41.3 ± 7.2</td>
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<tr>
<td>Disturbance</td>
<td>post 3 44.7 ± 7.3</td>
<td>41.0 ± 7.0</td>
<td>39.5 ± 6.3</td>
</tr>
</tbody>
</table>

Means were compared by using two-factor analysis of variance. Control: a passive recovery trial. Continuous AR: an active recovery with continuous exercise trial. Intermittent AR: an active recovery with intermittent exercise trial. (n=14, mean ± standard error). Tension-Anxiety: a main effect of trial; P = 0.77, a main effect of time; P = 0.08, trial × time interaction; P = 0.97 Depression: a main effect of trial; P = 0.58, a main effect of time; P = 0.24, trial × time interaction; P = 0.82 Anger-Hostility: a main effect of trial; P = 0.71, a main effect of time; P = 0.10, trial × time interaction; P = 0.29 Vigor: a main effect of trial; P = 0.48, a main effect of time; P = 0.70, trial × time interaction; P = 0.79 Fatigue: a main effect of trial; P = 0.83, a main effect of time; P = 0.002, trial × time interaction; P = 0.04 Confusion: a main effect of trial; P = 0.84, a main effect of time; P = 0.55, trial × time interaction; P = 0.42 Total Mood Disturbance: a main effect of trial; P = 0.40, a main effect of time; P = 0.99, trial × time interaction; P = 0.72 # Significantly different from the pre in the same trial (P < 0.05)
Our results indicate that AR with intermittent exercise increases subsequent exercise performance compared to passive recovery. In contrast, AR with continuous exercise did not increase Yo-Yo IR2 performance compared with passive recovery. Therefore, AR with intermittent, but not continuous, exercise may be an appropriate recovery method during short intervals between competitions.

The present findings that AR with intermittent exercise, but not AR with continuous exercise, increases subsequent exercise performance are consistent with the results of a previous study\(^{13}\). The reason for this increase may be the effect of warming up via AR. The potential mechanisms of increasing exercise performance by warming up are temperature-related, such as acceleration of metabolic reactions and increased nerve conduction rate, and non-temperature-related, such as elevation of baseline oxygen consumption and increase in blood flow to muscles\(^{14,15}\). When passive recovery is undertaken during the half-time period of a soccer game, the muscle temperature decreases by 1.3°C\(^{16}\). Muscle temperature is almost instantaneously increased by performing moderate-intensity exercise at a rate of 0.1-0.3°C/min\(^17\). Moreover, according to Dorado et al., AR increases the contribution of aerobic metabolism during subsequent high-intensity exercise at 120% of the maximal oxygen uptake compared with passive recovery\(^{18}\). Although it is not clear how the AR used in the present study increased these variables, impaired exercise performance in the control trial may be due to a lack of warming up via AR. However, continuous AR did not increase subsequent exercise performance. The combination of intensity and duration of warm-up is one of the important factors for improving subsequent exercise performance\(^{14,15}\). Bishop et al. have suggested that endurance exercise performance increases after warm up when an athlete is in a relatively non-fatigued state prior to subsequent exercise, but with an increased oxygen uptake\(^{15}\). Therefore, continuous AR for 15 min at 130 beats/min between high-intensity exercise may not be an appropriate intensity and duration of exercise for improving subsequent exercise performance. Therefore, the AR with intermittent exercise used in the present study may have a profound effect on the ability to perform subsequent exercise.

It was anticipated that lactic oxidation in the muscle during the recovery intervention would be higher in the continuous AR trial than in the intermittent AR trial since the duration of the exercise was greater during the continuous AR trial, while the intensity stayed the same. Interestingly, the percentage decrement of blood lactate concentration from post1 to post2 was found to be similar in the two AR trials. This confirms the findings of Yanaka et al.\(^{13}\) and Inazawa et al.\(^{19}\). This finding indicates that reducing blood lactate concentration is not necessary during AR with continuous exercise. Inazawa et al. have suggested the following reasons for the same decrement of blood lactate concentration in continuous and intermittent AR: 1) saturation of lactate uptake in the muscle, 2) preservation of lactate uptake by exercise because of the short interval duration of AR with intermittent exercise, and 3) acceleration of lactate uptake by repetition of exercise\(^{19}\). The same mechanisms could take place in the present study since the intensity and duration of AR with intermittent exercise were similar to those in the study of Inazawa et al.\(^{19}\).

The present study investigated whether AR influences objective and subjective fatigue levels. Salivary cortisol concentration has been recommended as an indicator of objective fatigue since venipuncture is not needed for its measurement\(^{20}\). Salivary cortisol is secreted immediately after exercise, and its concentration is related to the intensity and duration of the exercise\(^{21,22}\). In the present study, salivary cortisol concentration did not change during the recovery intervention period. Furthermore, there were no significant differences between trials in terms of most subscales of the POMS Questionnaire, which is used to evaluate subjective stress in soccer players\(^{23,24}\). In contrast, the fatigue score of the POMS at post3 compared to pre increased in the control and continuous AR trials, but not the intermittent AR trial. Corder et al. have suggested that AR at 50% of onset of blood lactate accumulation increased ratings of perceived exertion after subsequent exercise, but AR at 25% of onset of blood lactate accumulation decreased ratings of perceived exertion after subsequent exercise compared with AR at 50% of onset of blood lactate accumulation and passive recovery\(^{25}\). Therefore, the influence of AR on subjective fatigue may depend on the intensity of AR. The intensity of intermittent AR used in the present study may be insufficient to increase subjective fatigue. This is advantageous in practical applications since objective and subjective fatigue are an important factor affecting exercise performance\(^{26,26}\).

The present findings of increased subsequent intermittent exercise performance following AR with intermittent exercise after high-intensity exercise may have practical applications. For example, the amount of high-intensity running performed by soccer players and referees decreases in the first part of the second half of the game compared to the first part of the first half\(^{8,16,27}\). This reduction has been suggested to be due to a lack of physical preparation prior to the second half\(^{28}\). In soccer referees, AR with intermittent exercise may be a valuable conditioning method during the 15 min half-time period. Soccer referees have several duties in the half-time period (e.g., preparing their substitute before the second half and/or instructing players to return to the field to start the second half on time). AR with intermittent exercise can be performed alongside other duties during the intermission at half-time. However, the duration of the high-intensity exercise used in the present study was lower than in actual soccer games\(^{11}\). The distance covered by the average referee during the first half of an actual soccer game is approximately 5 to 6 km\(^{11}\). Moreover, the blood lactate concentration after the high-intensity exercise used in
the present study differed from that after the first half of an actual soccer game (present study: approximately 9.0 mmol/L, actual soccer games: approximately 3.4 mmol/L). Therefore, it is not clear whether AR with intermittent exercise used in the present study helps to increase exercise performance in the second half of a soccer game. It would be interesting to investigate whether the same results are obtained in a more realistic setting (i.e., a soccer game).

In conclusion, AR with intermittent exercise after high-intensity exercise increased Yo-Yo IR2 performance compared to passive recovery, whereas AR with continuous exercise did not show such an increase.

**Conflict of Interests**

The authors declare that there is no conflict of interests regarding the publication of this article.

**References**


