Received: 13 June 2019 | Revised: 22 January 2020 | Accepted: 18 February 2020
DOI: 10.1111/jjns.12335

ORIGINAL ARTICLE

JAPAN JOURNAL OF NURSING SCIENCE
WILEY

# Effects of postoperative active warming and early exercise on postoperative body temperature distribution: Non-blinded and randomized controlled trial

**Norihiro Kameda**[1] | **Shiroh Isono**[2] | **Shinobu Okada**[1]

[1]Frontier Practice Nursing, Graduate School of Nursing, Chiba University, Chiba, Japan

[2]Department of Anesthesiology, Graduate School of Medicine, Chiba University, Chiba, Japan

**Correspondence**
Norihiro Kameda, Faculty Doctoral student, Graduate School of Nursing, Chiba University, 1-8-1 Inohana, Chuo-ku, Chiba-City, Chiba 260-8672, Japan.
Email: norihiro0430@yahoo.co.jp

## Abstract

**Aim:** We tested a hypothesis that postoperative active warming and/or arm leg stretches reduce the difference between core and skin temperatures (primary variable) improving the peripheral circulation immediately after major abdominal surgery.

**Methods:** Fifty-one patients undergoing major abdominal surgeries were randomly assigned to receive one of three interventions immediately after surgery; routine care (control group), mild intermittent exercise on the bed (exercise group), and forced-air warming (warming group). Core and skin temperatures and perfusion index were continuously measured from anesthesia induction to 12 h after arrival at the ward.

**Results:** Core body temperature was maintained over 37°C with a relatively greater gap between core and skin temperatures over 1°C and reduced perfusion index in the early postoperative period in the control group. In the warming group, the reduced skin temperature at arrival at the ward approximated to the core temperature leading to significant reduction of the temperature gap and increasing the perfusion index to the preoperative level. Although less evident, both the temperature gap and peripheral perfusion significantly improved in the exercise group after 6 and 8 h after arrival at the ward, respectively.

**Conclusions:** Vasoconstriction in response to cessation after anesthesia and surgery serves to maintain core temperature, but impairs peripheral circulation. Active warming and intermittent mild exercise immediately after arrival at the ward reduces the temperature gap and improves peripheral circulation during the early postoperative period. While cost-effectiveness needs to be considered before clinical application of the intervention, the cost-free mild exercise may be a feasible option for improving postoperative patient care.

**KEYWORDS**

anesthesia, perfusion index, perioperative nursing, postoperative care, temperature management


© 2020 Japan Academy of Nursing Science

# 1 | INTRODUCTION

Inadvertent hypothermia used to be common in the early postoperative period before widespread use of intraoperative active warming with forced-air warming devices (Karalapillai & Story, 2008; Sessler, 2008). Current evidence indicates a decrease in tympanic temperature of 1–3°C is an independent risk factor for postoperative complications such as surgical site infections, postoperative myocardial ischemia and prolonged hospital stay, and maintenance of body temperature with active warming is demonstrated to reduce these complications (Frank et al., 1997; Kurz, 2008; Kurz, Sessler, & Lenhardt, 1996; Seamon et al., 2012; Sessler, 2016). Furthermore, prevention of postoperative hypothermia by means of intraoperative active warming is reported to achieve improved long-term mortality (Frey, Holm, Janson, Egenvall, & van der Linden, 2016; Karalapillai et al., 2009).

Although these evidences for temperature management during surgery had significant impact on the operating room practice to maintain normothermia of surgical patients within the operating room, there are few studies on body temperature of patients in the surgical ward after surgery (Lee, Wu, Shih, Lee, & Ho, 2015). While the first author was involved in perioperative care as operating room nurse and surgical ward nurse, he felt that temperature management for patients undergoing surgery was not effectively performed in the surgical ward compared to that in the operating room.

Frank et al. clarified mechanisms of postoperative increase of core temperature by assessing thermoregulatory responses such as vasoconstriction and shivering and plasma concentrations of inflammatory cytokines in addition to core and skin temperatures in patients undergoing a variety of surgical procedures (Frank, Kluger, & Kunkel, 2000; Sessler, 1997). They found that the maximum postoperative core temperature and interleukin (IL)-6 level were directly correlated with duration and invasiveness of the surgical procedure. Surgical inflammation evidenced by increased IL-6 is considered to elevate the body temperature set-point resulting in vasoconstriction and shivering which continue until the core temperature reaches the elevated set-point temperature. Because of the vasoconstriction, skin temperature decreases and the gap between core and peripheral temperatures increases. Any interventions to the mechanisms would lead to preventing postoperative vasoconstriction and shivering. One of the promising interventions is active warming evidenced as useful to reduce the difference between core and skin temperatures during surgery. Even mild exercise such as arm / leg stretches has an effect of vasodilation and possibly improves the temperature gap.

We aimed to test a hypothesis that postoperative active warming and/or arm / leg stretches reduce the difference between core and skin temperatures improving the peripheral circulation and the patient's comfort immediately after major abdominal surgery.

# 2 | METHODS

## 2.1 | Study design and participants

This prospective, non-blinded, and randomized controlled trial from March 2018 to July 2018 was performed at a university hospital and approved by the author's university ethics review board (29-70: Ethical Committee of the Graduate School of Nursing, Chiba University, Chiba, Japan).

The inclusion criteria were: male gender, age between 50 and 80 years, body mass index between 18.5 and 25 kg/m$^2$, patients undergoing laparotomy surgery. Exclusion criteria were: patients with metabolic diseases, patients with peripheral vascular disease, patients with serious preoperative and intraoperative complications, patients receiving continuous catecholamine infusion.

Based on the inclusion and exclusion criteria of this study and the operation schedule, the chief investigator approached candidates and disclosed the purpose of the study, the research methods and other precautions to the subjects prior to their participation. The participants' rights and privacy were protected throughout the study. Each participant completed a written consent form, and had the right to withdraw from the study at any given time for any given reason. Information pertaining to the patients' privacy was kept confidential. Findings of the research were also secured for each patient's bill of rights. At the end of the surgery, eligibility for this study was confirmed and the participant was randomly assigned to one of three intervention groups, those who underwent routine care (control group), those who received early intermittent exercise on the bed (exercise group), and those who received forced-air warming (warming group) based on the group name in the sealed envelopes which were prepared before start of this study. The randomization was designed to assign patients to a condition in a 1:1:1 ratio without blocking or stratification.

## 2.2 | Perioperative management and postoperative interventions

Surgeries of the participants were scheduled to start in the morning and general anesthesia was introduced around 8:30 a.m. and maintained during the surgery which was expected to be completed by 4:00 p.m. Therefore, postoperative care usually started around 5:00 p.m. in the surgical ward. Anesthesia techniques and surgical procedures were not standardized for this clinical study and were not biased by this study. During the surgery, room temperature of the operating theater was controlled between 24 and 26°C, and all patients were placed under a forced-air cover and received warming with a forced-air warmer (Bair Hugger™ 775, 3M). Anesthesiologists actively managed to maintain bladder temperature near 37°C during the surgery. Patients were sent to the ward after confirming core temperature above 36°C and alertness with stable cardiorespiratory status. While this study was conducted during spring in Japan, room temperature in the surgical ward was controlled based on the patient's comfort avoiding induction of cold sensation due to surrounding conditions.

Immediately after arrival at the ward, patients were treated with one of the following three different temperature managements.

#### 2.2.1 | Routine care (control)

Patients in the control group were covered with cotton blankets immediately after arrival at the surgical wards.

#### 2.2.2 | Early mild intermittent exercise on the bed (exercise)

During the postoperative period, the exercise group received a series of lower and upper limb gymnastics treatment, which was performed on their back on the flat bed. This exercise was conceived by the authors with reference to previous reports that active movement of the lower limbs showed improved blood flow in the lower limbs (Tanaka et al., 2016) and exercise of the upper body showed increased extremity venous blood flow (Caldwell et al., 2013). Details of a series of mild exercises performed by the exercise group are presented in Table 1. First, patients kept bending or extending both ankles for 5 s 50 times per section (ankle pump movement). Second, patients kept both legs straight, pressing knees down for 10 s 20 times per session (knee-pressing motion). Third, patients gently stretched the forearm muscles for 5 s 10 times per session. Lastly, patients squeezed a hand carpal expander (Hand Gripper 20LB, Neolight) as tightly as possible for 3 s 10 times per session. These exercises were performed in accordance with the researcher's detailed instructions during the postoperative period without prior training. The series of mild exercise started soon after arrival at the ward, and was repeated every hour until 9:00 p.m.

**TABLE 1** A series of mild exercises

| Session | Exercise | Implementation times | Required time (s) |
|---|---|---|---|
| 1 | Bending or extending both ankles | 5 s 50 times | 250 |
| 2 | Both legs straight pressing knees down | 10 s 20 times | 200 |
| 3 | Gently stretching the forearm muscles | 5 s 10 times | 50 |
| 4 | Squeezing a hand carpal expander | 3 s 10 times | 30 |
| | | | Total 530 |

#### 2.2.3 | Active warming with a forced-air warming blanket (warming)

In the warming group, active warming with a forced-air warming blanket covered by a cotton blanket was started immediately after arrival at the ward. The temperature of the forced-air warmer was set to "middle level" (38°C). Participants were asked every 10 min about their thermal comfort; when they felt overheated, active warming was stopped. Postoperative ambient temperatures were maintained near 26°C. After stopping the first consecutive warming, warming resumed according to the patient's symptoms and desires.

### 2.3 | Measurements of body temperatures and peripheral perfusion

Measurements were started prior to induction of general anesthesia and continued up to 12 h after arrival at the ward. In order to characterize and analyze changes of body temperatures and peripheral perfusion, the measurement values were obtained at various perioperative time points: prior to induction of general anesthesia, during operation, end of surgery, extubation of tracheal tube, leaving of operation room, arrival at the ward, 15, 30, 45 min after arrival at the ward, and every 1 h after arrival at the ward. Intraoperative values were obtained as an average value during the operation. The

**TABLE 2** Characteristics of the patients

| | Control (n = 16) | Exercise (n = 17) | Warming (n = 16) | *p* |
|---|---|---|---|---|
| Age of the patients (years) | 71.0 ± 7.7 | 72.1 ± 5.6 | 71.1 ± 8.4 | .90 |
| Body mass index (kg/m$^2$) | 21.9 ± 2.4 | 22.4 ± 2.1 | 21.7 ± 2.2 | .63 |
| ASA-PS | | | | .75 |
| 1 | 2 (12.5) | 1 (5.9) | 2 (12.5) | |
| 2 | 11 (68.8) | 13 (76.5) | 10 (62.5) | |
| 3 | 3 (18.8) | 3 (17.6) | 4 (25.0) | |
| Surgical procedure | | | | .67 |
| Pancreaticoduodenectomy | 6 (37.4) | 6 (35.3) | 7 (43.8) | |
| Hepatectomy | 5 (31.3) | 6 (35.3) | 5 (31.2) | |
| Other hepatobiliary surgery | 5 (31.3) | 5 (29.4) | 4 (25.0) | |
| Length of anesthesia (min) | 489 ± 161 | 476 ± 178 | 429 ± 108 | .51 |
| Length of operation (min) | 401 ± 158 | 391 ± 171 | 338 ± 101 | .44 |
| Intraoperative bleeding (mL) | 952 ± 727 | 1180 ± 1360 | 787 ± 567 | .50 |
| Intraoperative infusion volume (mL) | 3060 ± 1820 | 3110 ± 1480 | 2560 ± 767 | .48 |
| Intraoperative urine volume (mL) | 406 ± 416 | 370 ± 296 | 282 ± 210 | .53 |
| Hospital admission period (days) | 31.4 ± 20.1 | 30.3 ± 28.4 | 20.3 ± 8.7 | .27 |

*Note:* Values are mean ± SD or a number of patients with a percentage within the group.
Abbreviations: ASA-PS, American Society of Anesthesiologists Physical Status Classification System to stratify a patient's preoperative comorbid conditions (Hurwitz et al., 2017).

**TABLE 3** Intraoperative core temperature parameters

| | Control (n = l 6) | Exercise (n = 17) | Warming (n = 16) | *p* |
|---|---|---|---|---|
| Preanesthesia temperature (°C) | 36.9 ± 0.1 | 36.9 ± 0.1 | 36.9 ± 0.1 | .74 |
| Average intraoperative temperature (°C) | 36.9 ± 0.3 | 36.8 ± 0.3 | 36.9 ± 0.3 | .73 |
| Maximum intraoperative temperature (°C) | 37.5 ± 0.3 | 37.5 ± 0.3 | 37.6 ± 0.4 | .57 |
| Minimum intraoperative temperature (°C) | 36.1 ± 0.3 | 36.0 ± 0.3 | 36.1 ± 0.3 | .57 |
| Postoperative temperature (°C) | 37.3 ± 0.4 | 37.4 ± 0.3 | 37.5 ± 0.4 | .28 |
| Temperature fluctuation range (°C) | 1.3 ± 0.4 | 1.5 ± 0.3 | 1.5 ± 0.5 | .59 |

*Note:* Values are mean ± SD.

measurement values at arrival at the ward were considered to be a time control for the statistical analyses.

Core temperature was measured using SpotOn™ (Zero-Heat-Flux Cutaneous Thermometer, 3M). The measurement probe of SpotOn™ was attached to the forehead before induction of anesthesia, and was used for core temperature measurement from the preanesthesia to the postoperative temperature measurement period. Skin temperatures of chest, arm, thigh and leg were measured using an infrared skin thermometer (medical thermometer CISE®, UBIX). The body temperatures were recorded onto a laptop computer at 5-min intervals throughout the study period. Mean skin temperature was calculated by the following modification of the Ramanathan equation for four sites (Ramanathan, 1964): mean skin temperature = 0.3 (chest + arm) + 0.2(thigh + leg). Perfusion index (PI) was measured at a left hand forefinger using the bedside monitor (BSM-6701, Nihon Kohden, Japan) for assessment of peripheral perfusion.

## 2.4 | Assessments of postoperative clinical symptoms

Shivering was assessed 12 h after arrival at the ward. The degree of shivering was graded using a four-point scale (0 = no shivering; 1 = intermittent, low-intensity shivering; 2 = moderate shivering; 3 = continuous, intense shivering). Thermal discomfort and wound pain were assessed on the day after the surgery using unmarked

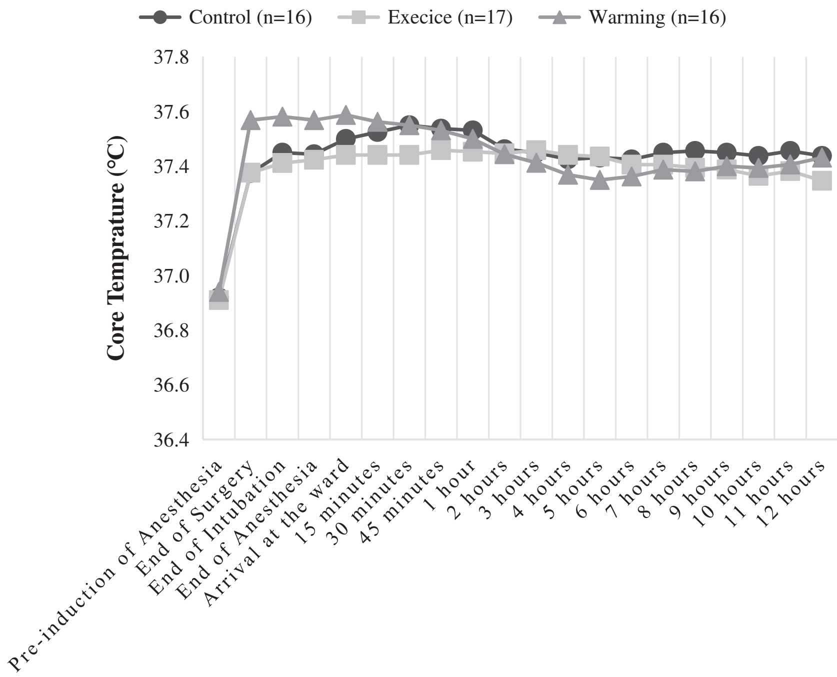


**FIGURE 1** Changes in core temperature in the three groups (control group, routine care; exercise group, mild intermittent exercise on the bed; warming group, active forced-air warming) before and after surgery. In the exercise group, the series of mild exercise started soon after arrival at the ward, and was repeated every hour until 9:00 p.m. (4.6 ± 2.0 times). In the warming group, active warming was started immediately after arrival at the ward (80.4 ± 44.7 min)

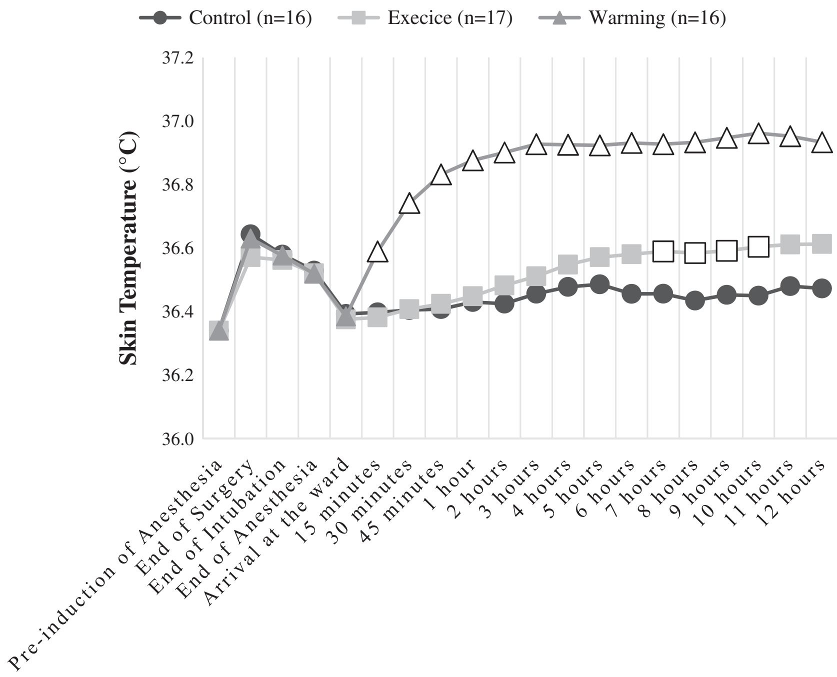


**FIGURE 2** Changes in skin temperature in the three groups (control group, routine care; exercise group, mild intermittent exercise on the bed; warming group, active forced-air warming) before and after surgery. In the exercise group, the series of mild exercise started soon after arrival at the ward, and was repeated every hour until 9:00 p.m. (4.6 ± 2.0 times). In the warming group, active warming was started immediately after arrival at the ward (80.4 ± 44.7 min). Open symbols indicate presence of a statistically significant difference from the control group

new 100 visual analog scale (VAS) sheets. For thermal discomfort, 0 and 100 indicated "completely comfortable" and "worst imaginable cold", respectively. For wound pain, 0 and 100 indicated "no pain at all" and "painful as bad as it could be", respectively.

## 2.5 | Statistical analyses

To our knowledge, there is no previous study assessing the difference between core and skin temperatures (the primary outcome) in surgical patients during the immediate postoperative period while it was reported to be 3.8 ± 1.0°C (mean ± SD) in surgical patients before anesthesia induction (Frank, Shir, Raja, Fleisher, & Beattie, 1994). In order to calculate appropriate sample size in this study, we assumed a similar standard deviation (1.0°C) in our study population and expected more than 0.5°C difference between control and intervention groups as a clinically meaningful effect. Accordingly, required total sample size was estimated to be 42 subjects (G-POWER version 3.1 software: [F tests, effect size = .5,

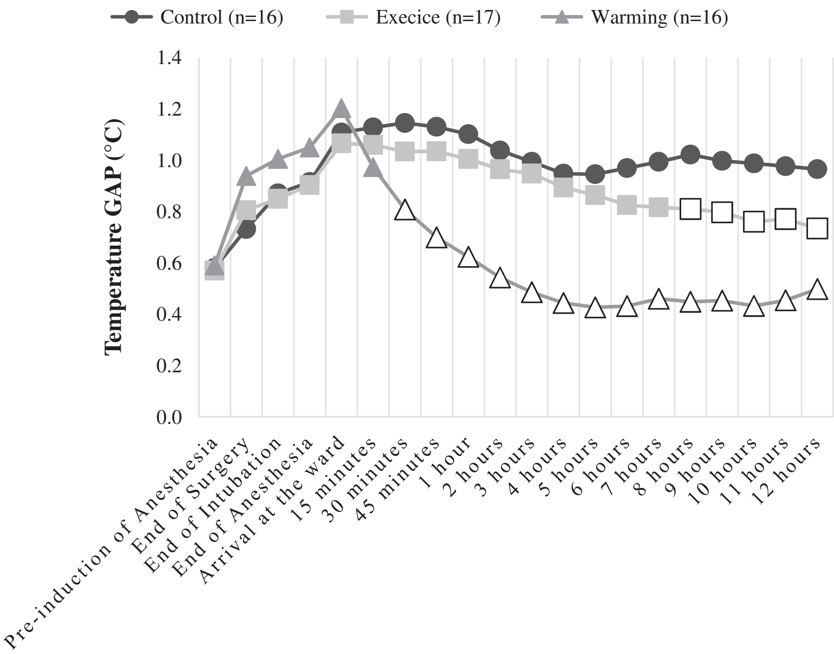


**FIGURE 3** Changes in gap between skin temperature and core temperature in the three groups (control group, routine care; exercise group, mild intermittent exercise on the bed; warming group, active forced-air warming) before and after surgery. In the exercise group, the series of mild exercise started soon after arrival at the ward, and was repeated every hour until 9:00 p.m. (4.6 ± 2.0 times). In the warming group, active warming was started immediately after arrival at the ward (80.4 ± 44.7 min). Open symbols indicate presence of a statistically significant difference from the control group

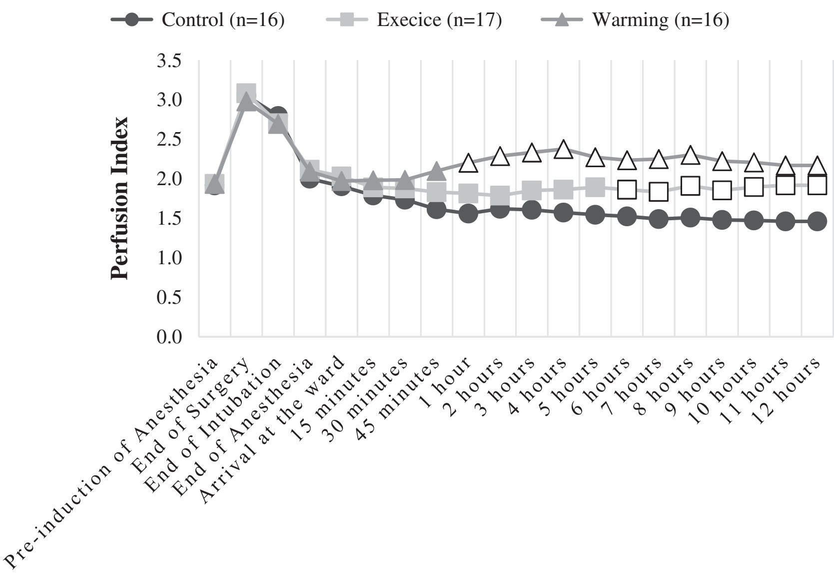


**FIGURE 4** Changes in perfusion index in the three groups (control group, routine care; exercise group, mild intermittent exercise on the bed; warming group, active forced-air warming) before and after surgery. In the exercise group, the series of mild exercise started soon after arrival at the ward, and was repeated every hour until 9:00 p.m. (4.6 ± 2.0 times). In the warming group, active warming was started immediately after arrival at the ward (80.4 ± 44.7 min). Open symbols indicate presence of a statistically significant difference from the control group

$\alpha = .05$ (two tailed), $\beta = .8$, number of groups = 3] for one-way analysis of variance [ANOVA]). Considering possible exclusion during operation due to intraoperative complications and catecholamine use, 51 patients in total (17 patients for each group) were predetermined as an optimal sample size for this study. All statistical analyses were performed using statistics software IBM SPSS® Statistics 23.0. Continuous, normally distributed variables were analyzed using one-way ANOVA and Scheffe's F test. Differences between the groups were compared with Tukey test. Pearson $\chi^2$ test was used for comparing risk factors among groups. Pearson's correlation analysis was used to analyze the correlation between PI and temperature gap. All values are expressed as means ± SD. $p < .05$ was considered to be significant.

# 3 | RESULTS

## 3.1 | Patients' characteristics and intervention status

Seventeen patients were initially enrolled in each group, but one patient in the control group and one in the warming group were excluded from the analysis due to continuous infusion of catecholamine after the surgery. Patient characteristics and features of anesthesia managements and surgical procedures are presented in Table 2. All patients underwent hepatobiliary pancreatic surgeries. No significant differences were observed among the three groups. In the exercise group, a series of postoperative exercise was repeated 4.6 ± 2.0 times. In the warming group, postoperative active warming was performed for 80.4 ± 44.7 min. Although the core temperatures significantly decreased in all three groups during anesthesia and surgery, no differences were found in any of the body temperatures before or during surgery among the groups (Table 3).

## 3.2 | Body temperatures after surgery

Figures 1 and 2 show changes of the core and skin temperatures during the first 12 h after arrival at the ward, respectively. During the postoperative periods, changes of core temperatures did not differ between the groups. Also, no differences were found in the mean skin temperature between the three groups until arriving at the ward. Notably, in the warming group, skin temperature rapidly increased within 1 h after arrival at the ward, and remained higher than the control and exercise groups. Although less effective than the warming group, skin temperature in the exercise group gradually increased and remained significantly higher than the control group for the last 6 h of the measurements.

Temperature gaps (primary variable) calculated as the difference between core and skin temperatures before anesthesia and surgery were 0.58 ± 0.17, 0.57 ± 0.14, and 0.59 ± 0.05°C in the control, exercise and warming groups, respectively. Figure 3 shows changes in the temperature gaps for each of the groups after surgery. The temperature gaps gradually increased during the surgery and remained larger until arriving at the ward in all groups with no differences between the three groups. However, after arrival at the wards the gap significantly decreased and reached the preoperative value within 1 h in response to active warming with the forced-air warming blanket (warming group). The temperature gap remained smaller for the whole postoperative period despite cessation of the active warming. Although less effective than the active warming, exercise procedures repeated at every 1 h after arriving at the ward achieved significant differences in the temperature gap from the control group after 8 h after arrival in the surgical ward (exercise group).

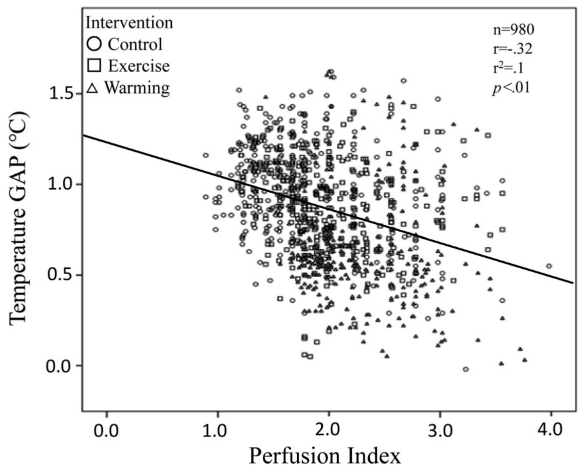


**FIGURE 5** Correlation between perfusion index and gap between core and skin temperatures (temperature gap)

## 3.3 | PI and its correlation with the temperature gap

The PIs before anesthesia and surgery were 1.91 ± 0.42, 1.93 ± 0.39, 1.93 ± 0.33 in the control, exercise and warming groups, respectively.

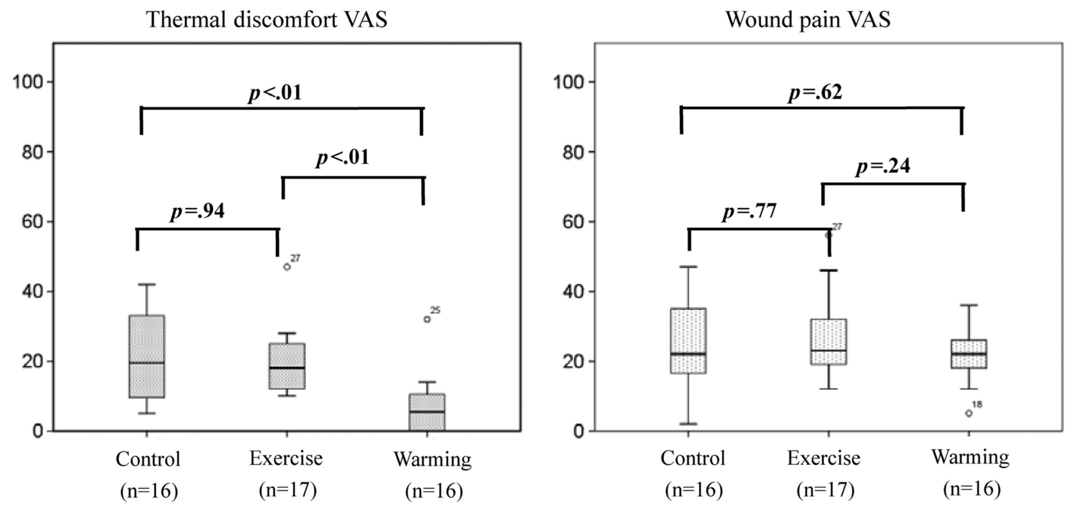


**FIGURE 6** Box plots presenting comparisons of visual analog scales (VAS) for thermal discomfort and wound pain in the three groups (control group, routine care; exercise group, mild intermittent exercise on the bed; warming group, active forced-air warming). Median values are indicated by horizontal bars within each box; bars above and below each box represent 25 and 75 percentiles, end of vertical lines denote 5 and 95 percentiles

Figure 4 shows changes of PI during the postoperative period. The PI increased during the surgery in all groups, but decreased and almost reached the preoperative value at arrival at the ward with no differences between the three groups. In the warming group, the PI gradually increased during the active warming and remained higher during the postoperative period even after cessation of the active warming. Although less effective than the active warming, exercise procedures repeated at every 1 h after arriving at the ward achieved significant difference in the PI from the control group after the last 7 h of the measurements. Figure 5 shows association between PI and the temperature gap demonstrating statistically significant but weak indirect correlation between them ($r = .32$, $p < .01$).

### 3.4 | Postoperative clinical symptoms

Intermittent, low-intense shivering (grade 1) was observed postoperatively in 18.8%, 5.9% and 0% in control, exercise and warming groups, respectively ($p = .15$). Figure 6 shows VAS scores for postoperative thermal discomfort and wound pain. The VAS score of postoperative thermal discomfort was significantly smaller in the warming group than the control and exercise groups suggesting achievement of higher comfortableness and acceptance of the active warming whereas no difference was observed between the exercise and control groups. The VAS scores for wound pain did not differ between the three groups.

## 4 | DISCUSSIONS

This study aimed to investigate effectiveness of postoperative active warming and exercise on postoperative body temperatures and peripheral circulation in patients undergoing major abdominal surgery. Both active warming and early intermittent mild exercise effectively reduced the gap between core and skin temperatures by increasing skin temperature and improved peripheral circulation even after cessation of the procedures while the active warming was more effective and comfortable than the exercise.

### 4.1 | Postoperative changes of body temperatures with routine care

Few studies examined changes of body temperatures immediately after the surgery under general anesthesia while environmental factors on body temperature significantly change during this period. After the surgery is completed, active warming is often interrupted by removal of the surgical drapes, wiping of the disinfectant, wound dressing, and X-ray radiography. Furthermore, blankets alone are put on the patient during transportation from operating room to the ward. Despite the interruption and cessation of the active warming, the core temperature was maintained postoperatively. We consider this was due to significant reduction of skin temperature and vasoconstriction preventing heat loss from the body. Our results clearly indicate recovery of thermoregulatory control immediately after anesthesia and surgery in accordance with the previous studies (Sessler, Rubinstein, & Moayeri, 1991). Although vasoconstriction is beneficial to maintain core temperature, it impairs peripheral circulation including the surgical wound possibly increasing surgical site infection risk. It should be noticed that vasoconstriction and impaired peripheral circulation continue throughout the postoperative period without interventions. The result urges us to minimize the cessation of active warming in the operating room, and also to continue the active warming or other interventions for preventing vasoconstriction during transportation to the ward (Scheck et al., 2004). The discrepancy between the PI and the temperature gap observed in this study further suggests clinical usefulness of monitoring of the peripheral circulation with using the PI rather than measurements of skin and core temperature during the postoperative period (Keramidas, Geladas, Mekjavic, & Kounalakis, 2013).

### 4.2 | Clinical implications of postoperative active warming

Active warming with a forced-air warming blanket is a well-established intervention to maintain core temperature during anesthesia and surgery (Alparslan et al., 2018; John et al., 2016). As expected, our results further supported effectiveness of the postoperative active warming on significant reduction of difference between core and skin temperatures and significant improvement of peripheral circulation. Importantly, the beneficial effects of active warming continued throughout the postoperative period despite cessation of the active warming. Furthermore, the patients felt more comfortable with the postoperative active warming. Postoperative routine application of the forced-air warming blanket would significantly change strategies for postoperative management of body temperature and possibly influence short-term and long-term outcomes of the surgery. However, costs for installation of the forced-air device and disposable blanket as well as the extra labor for the nursing staff are significant limitations for the clinical application of this intervention.

### 4.3 | Clinical implications of postoperative mild exercise

This is the first study demonstrating effectiveness of early postoperative intermittent mild exercise on reduction of difference between core and skin temperatures and improvement of peripheral circulation even after cessation of the exercise in patients undergoing major abdominal surgery, although the effect was significantly smaller than the active warming. The mechanisms of the effectiveness of mild exercise were not clarified in this study. However, it may differ from those with active warming. Low-intensity exercise is reported to increase core body temperature while maintaining a skin temperature by cooling in healthy volunteers possibly by increase of heat production (Fujii et al., 2017) and decrease in the threshold of core temperature for shivering (Fujimoto et al., 2019). We did not observe increase of core temperature in postoperative patients during the mild intermittent exercise and therefore, the results may not be explained by exercise-induced heat production. With using sophisticated imaging techniques, Steeden et al. demonstrated that even mild lower limb exercise in the supine posture is reported to increase cardiac output and decrease systemic vascular resistance, indicating improvement of peripheral circulation while they did not measure body temperature (Steeden, Atkinson, Taylor, & Muthurangu, 2010). Therefore, in our study, improvement of peripheral circulation by mild exercise possibly leads to redistribution of body temperature and then delayed but sustained increase of skin temperature. Early postoperative mobilization is recommended for preventing postoperative complications and development of sarcopenia leading to improvement of surgical outcomes (Castelino et al., 2016; Ramos Dos Santos, Aquaroni Ricci, Aparecida Bordignon Suster, de Moraes Paisani, & Dias Chiavegato, 2017). While no study, to our knowledge, tested clinical usefulness of early postoperative mild exercise which would be worth including in the postoperative recovery protocol. Unlike the postoperative active warming, the early supine exercise is safe and cost-free, and has possible additional favorable effects such as prevention of deep venous thrombosis formation (Li et al., 2016; Rostagno, 2013). Future studies need to explore optimal intensity and interval of the exercise for maximizing its clinical usefulness.

### 4.4 | Relevance to improving quality of nursing practice

Appropriate management of a patient's body temperature is a major task for nurses working in the surgical ward. Our results suggest that nurses could effectively warm the patient's whole body with using the forced-air warming blanket to maintain normal body temperature after surgery to improve nursing care not only for prevention of shivering and improvement of thermal comfort but also for improvement of peripheral circulation, possibly leading to prevention of various postoperative complications. Furthermore, nurses could actively assist postoperative mild exercise for normalization of body temperature and improvement of peripheral circulation. This study clearly demonstrated significant roles of surgical ward nurses in improving quality of postoperative nursing practice by developing the postoperative temperature management protocol including the interventions tested in this study.

### 4.5 | Limitations of the study

There are several limitations of this study. First, the study population is limited to patients undergoing hepatobiliary pancreatic surgery which has a significant impact on the intra- and postoperative changes of body temperature. Second, protocols for the interventions were not strictly controlled and might have influenced the results of the study. In particular, different exercise programs would have had greater impact on the body temperature. Third, the core temperature was relatively higher at arrival at the ward and the results might have been different if the core temperature were lower than 37°C.

## 5 | CONCLUSION

In conclusion, vasoconstriction in response to cessation of active warming after anesthesia and surgery serves to maintain core temperature, but increases temperature gap between core and skin temperatures. Both active warming and intermittent mild exercise during the early postoperative period effectively reduce the temperature gap and improve peripheral circulation even after cessation of the interventions.

While the active warming was more effective than the exercise, cost-effectiveness needs to be improved before clinical application of the active warming, but the cost-free exercise may be a feasible option for improving postoperative patient care.

## ACKNOWLEDGEMENTS

The authors thank the participants of this study. We also thank the hospital staff who cooperated in our research.

## CONFLICT OF INTEREST

The authors declare no conflict of interest in this investigation.

## AUTHOR CONTRIBUTIONS

N.K. and S.I. contributed to the conception and design of this study; N.K. performed the statistical analysis and drafted the manuscript; and S.I. and S.O. critically reviewed the manuscript and supervised the whole study process. All authors read and approved the final manuscript.

## REFERENCES

Alparslan, V., Kus, A., Hosten, T., Ertargin, M., Ozdamar, D., Toker, K., & Solak, M. (2018). Comparison of forced-air warming systems in prevention of intraoperative hypothermia. *Journal of Clinical Monitoring and Computing*, *32*(2), 343–349.

Caldwell, K., Prior, S. J., Kampmann, M., Zhao, L., McEvoy, S., Goldberg, A. P., & Lal, B. K. (2013). Upper body exercise increases lower extremity venous blood flow in deep venous thrombosis. *Journal of Vascular Surgery Venous and Lymphatic Disorders*, *1*(2), 126–133.

Castelino, T., Fiore, J. F., Niculiseanu, P., Landry, T., Augustin, B., & Feldman, L. S. (2016). The effect of early mobilization protocols on postoperative outcomes following abdominal and thoracic surgery: A systematic review. *Surgery*, *159*(4), 991–1003.

Frank, S. M., Fleisher, L. A., Breslow, M. J., Higgins, M. S., Olson, K. F., Kelly, S., & Beattie, C. (1997). Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events. A randomized clinical trial. *Journal of the American Medical Association*, *277*(14), 1127–1134.

Frank, S. M., Kluger, M. J., & Kunkel, S. L. (2000). Elevated thermostatic setpoint in postoperative patients. *Anesthesiology*, *93*(6), 1426–1431.

Frank, S. M., Shir, Y., Raja, S. N., Fleisher, L. A., & Beattie, C. (1994). Core hypothermia and skin-surface temperature gradients. Epidural versus general anesthesia and the effects of age. *Anesthesiology*, *80*(3), 502–508.

Frey, J., Holm, M., Janson, M., Egenvall, M., & van der Linden, J. (2016). Relation of intraoperative temperature to postoperative mortality in open colon surgery—An analysis of two randomized controlled trials. *International Journal of Colorectal Disease*, *31*(3), 519–524.

Fujii, N., Aoki-Murakami, E., Tsuji, B., Kenny, G. P., Nagashima, K., Kondo, N., & Nishiyasu, T. (2017). Body temperature and cold sensation during and following exercise under temperate room conditions in cold-sensitive young trained females. *Physiological Reports*, *5*(20), 1–13.

Fujimoto, T., Tsuji, B., Sasaki, Y., Dobashi, K., Sengoku, Y., Fujii, N., & Nishiyasu, T. (2019). Low-intensity exercise delays the shivering response to core cooling. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*, *316*(5), 535–542.

Hurwitz, E. E., Simon, M., Vinta, S. R., Zehm, C. F., Shabot, S. M., Minhajuddin, A., & Abouleish, A. E. (2017). Adding examples to the ASA-physical status classification improves correct assignment to patients. *Anesthesiology*, *126*(4), 614–622.

John, M., Crook, D., Dasari, K., Eljelani, F., El-Haboby, A., & Harper, C. M. (2016). Comparison of resistive heating and forced-air warming to prevent inadvertent perioperative hypothermia. *British Journal of Anaesthesia*, *116*(2), 249–254.

Karalapillai, D., & Story, D. (2008). Hypothermia on arrival in the intensive care unit after surgery. *Critical Care and Resuscitation*, *10*(2), 116–119.

Karalapillai, D., Story, D. A., Calzavacca, P., Licari, E., Liu, Y. L., & Hart, G. K. (2009). Inadvertent hypothermia and mortality in postoperative intensive care patients: Retrospective audit of 5050 patients. *Anaesthesia*, *64*(9), 968–972.

Keramidas, M. E., Geladas, N. D., Mekjavic, I. B., & Kounalakis, S. N. (2013). Forearm-finger skin temperature gradient as an index of cutaneous perfusion during steady-state exercise. *Clinical Physiology and Functional Imaging*, *33*(5), 400–404.

Kurz, A. (2008). Thermal care in the perioperative period. *Best Practice & Research Clinical Anaesthesiology*, *22*(1), 39–62.

Kurz, A., Sessler, D. I., & Lenhardt, R. (1996). Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of wound infection and temperature group. *The New England Journal of Medicine*, *334*(19), 1209–1215.

Lee, W. P., Wu, P. Y., Shih, W. M., Lee, M. Y., & Ho, L. H. (2015). The effectiveness of the newly designed thermal gown on hypothermic patients after spinal surgery. *Journal of Clinical Nursing*, *24*(19–20), 2779–2787.

Li, Y., Guan, X. H., Wang, R., Li, B., Ning, B., Su, W., … Li, H. Y. (2016). Active ankle movements prevent formation of lower-extremity deep venous thrombosis after orthopedic surgery. *Medical Science Monitor*, *22*, 3169–3176.

Ramanathan, N. L. (1964). A new weighting system for mean surface temperature of the human body. *Journal of Applied Physiology*, *19*, 531–533.

Ramos Dos Santos, P. M., Aquaroni Ricci, N., Aparecida Bordignon Suster, É., de Moraes Paisani, D., & Dias Chiavegato, L. (2017). Effects of early mobilisation in patients after cardiac surgery: A systematic review. *Physiotherapy*, *103*(1), 1–12.

Rostagno, C. (2013). Prophylaxis of venous thromboembolism in major orthopedic surgery: A practical approach. *Cardiovascular & Hematological Agents in Medicinal Chemistry*, *11*(3), 230–242.

Scheck, T., Kober, A., Bertalanffy, P., Aram, L., Andel, H., Molnár, C., & Hoerauf, K. (2004). Active warming of critically ill trauma patients during intrahospital transfer: A prospective, randomized trial. *Wiener Klinische Wochenschrift*, *116*(3), 94–97.

Seamon, M. J., Wobb, J., Gaughan, J. P., Kulp, H., Kamel, I., & Dempsey, D. T. (2012). The effects of intraoperative hypothermia on surgical site infection: An analysis of 524 trauma laparotomies. *Annals of Surgery*, *255*(4), 789–795.

Sessler, D. I. (1997). Perioperative thermoregulation and heat balance. *Annals of the New York Academy of Sciences*, *813*, 757–777.

Sessler, D. I. (2008). Temperature monitoring and perioperative thermoregulation. *Anesthesiology*, *109*(2), 318–338.

Sessler, D. I. (2016). Perioperative thermoregulation and heat balance. *Lancet*, *387*(10038), 2655–2664.

Sessler, D. I., Rubinstein, E. H., & Moayeri, A. (1991). Physiologic responses to mild perianesthetic hypothermia in humans. *Anesthesiology*, *75*(4), 594–610.

Steeden, J. A., Atkinson, D., Taylor, A. M., & Muthurangu, V. (2010). Assessing vascular response to exercise using a combination of real-time spiral phase contrast MR and noninvasive blood pressure measurements. *Journal of Magnetic Resonance Imaging*, *31*(4), 997–1003.

Tanaka, K., Kamada, H., Shimizu, Y., Aikawa, S., Nishino, T., Ochiai, N., … Yamazaki, M. (2016). The use of a novel in-bed active leg exercise apparatus (LEX) for increasing venous blood flow. *Journal of Rural Medicine*, *11*(1), 11–16.

**How to cite this article:** Kameda N, Isono S, Okada S. Effects of postoperative active warming and early exercise on postoperative body temperature distribution: Non-blinded and randomized controlled trial. *Jpn J Nurs Sci*. 2020; 17:e12335. https://doi.org/10.1111/jjns.12335