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Forearm Skin Blood Flow After Kinesiology Taping in Healthy Soccer Players: An Exploratory Investigation

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Context: Kinesiology tape (KT) has become popular among athletes for both injury prevention and rehabilitation due to its reported therapeutic effects, including facilitation of lymphatic flow and enhanced peripheral blood flow. However, evidence to support such claims is insufficient.

Objective: To determine whether KT improves skin blood flow (SkBF) responses in young, elite soccer players.

Design: Randomized crossover study.

Setting: Research laboratory.

Patients or Other Participants: Thirteen healthy, elite, adolescent male soccer players (age = 14.7 ± 0.6 years).

Intervention(s): Participants completed 2 experimental trials; during trial 1, the volar aspect of the dominant forearm was taped. Forearm SkBF was measured within the taped area and 3 cm lateral to the taped area. During trial 2, no tape was applied to either site. Both trials were performed within 7 days.

Main Outcome Measure(s): Baseline and maximal thermally (42°C) stimulated SkBF responses were assessed using laser Doppler flowmetry. Continuously measured SkBF and derived mean arterial pressure obtained at 5-minute intervals were used to calculate cutaneous vascular conductance (CVC), the primary outcome measure.

Results: No differences were observed for baseline SkBF or CVC between trials or measurement sites. After local heating, no differences were evident for SkBF or CVC between trials or measurement sites.

Conclusions: Our findings suggest that, in healthy, trained adolescent males, KT was not associated with increased forearm SkBF.

Key Words: microcirculation, endothelial-dependent vasodilation, laser Doppler flowmetry

Key Points

- Kinesio taping did not enhance skin blood flow in healthy, trained, adolescent males.
- Kinesio taping did not induce skin blood flow changes through neural or endothelial pathways.

Kinesiology tape (KT) is an elastic, therapeutic tape reportedly designed to facilitate the healing of traumatized tissue, thereby providing symptomatic relief for numerous medical conditions and injuries ranging from patellar dislocation to tendinopathies, such as lateral epicondylitis.[1] Various claims exist concerning the efficacy of KT, including correction of joint kinematics by assisting muscle or joint position,[2] increasing pain-free range of motion,[3,4] assisting and maintaining muscular strength,[5–7] modulating pain,[8,9] enhancing proprioception and kinesthesia through re-education of the neuromuscular system,[10,11] facilitating lymphatic flow,[1,12,13] and enhancing peripheral blood flow.[14]

Although considerable anecdotal support exists for KT-induced improvements in blood flow, scientific evidence is limited; to date, only 3 studies have specifically examined KT effects on blood flow.[14–16] However, we are unable to draw meaningful conclusions from these studies due to inconsistent outcomes and a lack of scientific rigor and detail. Fundamental limitations, including the absence of a robust method for Doppler assessment[17] and small, poorly defined study samples, render the interpretation and application of their findings impossible.[14–16] Furthermore, no authors to date have attempted to elucidate the underpinning physiologic mechanism by which any KT-related improvements in blood flow were induced. The suggested theoretical mechanism by which KT purportedly achieves a circulatory response relates to the lifting of skin from the underlying fascia, thereby increasing the interstitial space to encourage blood flow.[16] However, no scientific evidence supports this theory, and thus, more detailed and robust research into KT is warranted.

Laser Doppler flowmetry (LDF) allows the measurement of skin blood flow (SkBF) over time and in response to a given stimulus and is therefore a suitable medium through which to evaluate the SkBF effect of KT. Microvascular endothelial function, which is instrumental in the intrinsic regulation of vascular tone,[18] can also be examined by assessing the LDF SkBF response to local thermal provocation.[17,19,20] Maximal vasodilatation of skin blood vessels can be achieved with sustained heating to 42°C; however, the response is biphasic.[17,19] The initial neurogenic response occurs within 3–5 minutes of heating and primarily results from stimulation of C-fiber afferent sensory nerves.[17,19,21] The second phase of the response is largely mediated by nitric oxide (NO) and is characterized by a vasodilatory response that reaches a plateau after 25–30 minutes.[19,21] Hence, stimulating maximal SkBF in this way allows the evaluation of 2 potential mechanisms that may evoke the reported circulatory improvements after KT application.

Robust scientific research is not available to support claims that KT enhances blood flow. Furthermore, the mechanisms by which KT induces any such effects are

Table 1. Participant Characteristics (N = 13)

Characteristic	Mean[a]
Age, y	14.7 ± 0.6
Mass, kg	67.9 ± 8.8
Height, cm	178.4 ± 4.7
Body mass index	15
Baseline pressure	
Systolic blood	116 ± 9
Diastolic blood	56 ± 6
Mean arterial	75 ± 4
Tanner stage[b]	
3	15
4	46
5	39
Soccer experience	
Training, h/wk	12 ± 3
Training, mo/y	10 ± 1
Length of career, y	8 ± 2
Competitive match participation, y	8 ± 2

[a] Values for age, mass, height, baseline systolic blood pressure, baseline diastolic blood pressure, baseline mean arterial pressure, and soccer status are expressed as mean ± SD.

[b] Values for Tanner stages reflect the percentage of participants in each stage.

unknown. Identifying such a mechanism is fundamental to establishing how KT may be beneficial in facilitating the rehabilitation of injured tissue. In addition, having a sound understanding of how KT works is central to practitioners being able to optimize the clinical benefits of KT application for their clients. The aims of our study therefore were, first, to examine the effect of KT application on forearm SkBF at rest and, second, to investigate whether endothelial-dependent vasodilation was augmented in response to KT application with thermal stimulation.

METHODS

Participants

Thirteen highly trained adolescent male soccer players (Table 1) were recruited from the Youth Academy of a Premier League soccer club. Maturity status was determined using the validated method of Tanner self-assessment,[22] and stature (seca 217 stadiometer; seca UK, Birmingham, England, UK) and body mass (Brecknell SBI 100 scale; Avery Weigh-Tronix, LLC, Fairmont, MN) were recorded using standardized protocols. Training status and physical activity profiles were assessed using a training and physical activity questionnaire (Table 1).[23,24] All participants were healthy; had no known cardiovascular or microvascular disorders, including erythromelalgia or Raynaud phenomenon; and were not taking any medication. Additionally, participants reported no previous injury to the dominant arm or skin allergy that might hinder KT application. To ensure that no dermatologic allergic reaction would occur, we performed a small patch test of KT and medical tape 1 week before testing. Participants were screened for hirsute forearms and, if necessary, were asked to shave the relevant area at least 24 hours before testing.

On each study day, participants refrained from both aerobic and resistance exercise for at least 12 hours and were required to fast overnight, abstaining from food and drink containing caffeine or a high sugar or fat content for at least 6 hours before testing.[25] Before testing, (1) sips of water were permitted up to 2 hours prior to ensure euhydration, (2) participants were asked to empty their bladders, and (3) participants completed questionnaires to confirm that they had complied with instructions relating to diet, exercise, and medication.

Written assent and consent was obtained from all participants and parents or guardians, respectively. The study was approved by a local university ethics committee.

Study Design

To account for diurnal variation and ambient temperature effects, we collected data between 7:00 AM and 11:00 AM in a quiet, temperature-controlled room (23°C ± 1°C).[17,25] Participants completed 2 experimental trials, a taped trial (T) and a nontaped trial (NT), within 7 days, in a randomized crossover design. During each trial, baseline and maximal thermally stimulated SkBF responses were assessed in the dominant forearm, using 2 probes during each trial: a condition probe (T or NT) and a control probe (CON1 or CON2).

Laser Doppler Flowmetry

Microvascular function measurements. ***Test Preparation.*** We selected the dominant arm for testing because vasculature varies between the dominant and contralateral sides due to exercise adaptation.[26–28] The forearm was chosen over the lower limb to prevent potential influences from any previous or between-tests vascular insult associated with the lower limb musculoskeletal injuries that are common in soccer players.

After a 20-minute stabilization period, we calibrated the equipment using a motility standard according to the manufacturer's guidelines.[17] To minimize fluctuations in SkBF from motion artefact, participants assumed a comfortable, supine position on a plinth throughout each trial, with the head slightly elevated and the hand of the test arm relaxed and supinated.[17,25,29] After sterilization of the forearm, 2 probes were placed at least 4 cm apart on the volar aspect. Visible vascularity, hair follicles, and dermatologic lesions were avoided.[17,29] Measurements of probe sites to the nearest millimeter, using anatomical and skin surface landmarks for reference, were recorded and a photograph was taken to reduce variability between conditions.[17]

Taped Trial. With the dominant arm in a passively stretched position, we applied a single 15-cm I-strip of Kinesio Tex Gold (KT; Kinesio, Albuquerque, NM) to the volar aspect of the forearm (Figure 1).[1] Increased blood flow has been suggested to arise from a space-correction technique, which uses a 25%–50% stretch.[1] Manufacturers consider I-strips to be 1 of the main application techniques used to create the lifting effect associated with space correction.[1] Therefore, we chose I-strips as our taping technique and used a 10% manual stretch in addition to the 25% stretch that is reportedly applied to the tape during the manufacturing process to give a combined stretch of 35%, which is within the recommended range of 25%–50%. The

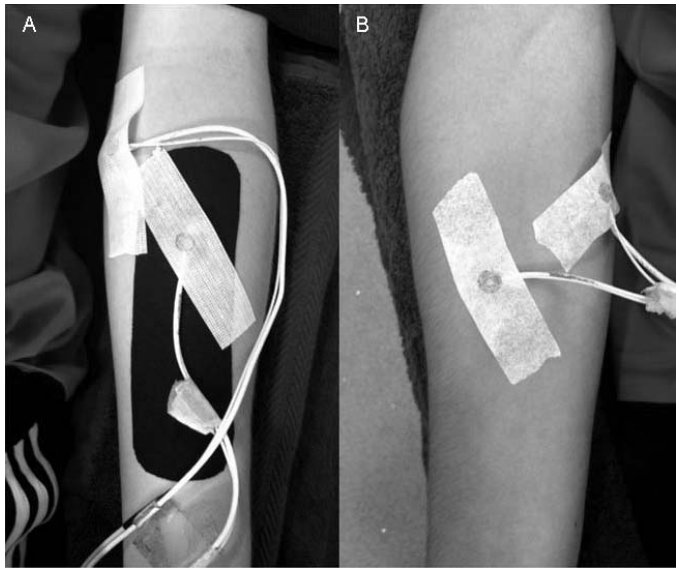

Figure 1. Participants' forearms with probes in situ, undergoing A, taped trial (left arm) and, B, nontaped trial (right arm).

degree of stretch was determined using the concept outlined by Kase et al[1] regarding maximal available stretch (100%) being 40% of the overall KT length (eg, the maximal stretch of a 10-cm strip would be 14 cm, and a 25% stretch would be 11 cm). Therefore, a 10% manual stretch of the 15-cm strip resulted in the KT length being 15.6 cm for the forearm application. The 10% stretch was applied to the middle third of the KT strip, with no stretch at the ends.[1] To allow probe placement in the center of the KT strip, a 10-mm hole (the size of the probe) was precut in the tape to allow for more accurate SkBF measurement. One member of the research team, who had experience in KT usage, performed all KT applications during the study.

After KT application, participants underwent a 15-minute acclimation period. The probe was then placed on the taped site and allowed to stabilize for 1 minute before baseline measurement. The KT remained in situ for the duration of testing. A second probe (CON1) was positioned in the collateral area, 3 cm lateral to the taped area and at least 4 cm from the taped probe.

Nontaped Trial. During the NT trial, no tape was applied to either probe site (NT or CON2; Figure 1). After a 15-minute acclimation period, the LDF probes were positioned at the appropriate sites on the volar aspect of the forearm and secured with medical tape.

Laser Doppler Flowmetry Protocol: T and NT

We conducted the protocol (Figure 2) using a 2-channel laser Doppler (PeriFlux 5000; Perimed AB, Stockholm, Sweden) and 10-mm integrated, small-angled thermostatic laser Doppler probes (Probe 457; Perimed AB) to allow simultaneous heating and signal measurements. After a 15-minute acclimation period, a 20-minute thermoneutral (32°C) baseline period began, from which time cutaneous red blood cell flux was recorded. After the baseline period, maximal NO-dependent cutaneous vasodilation was induced by heating thermostatic probes incrementally to 42°C (1°C every 10 seconds),[21] which was maintained for 30 minutes until a stable plateau was reached. Participants reported no heating-induced pain during this period. Data were recorded using Perisoft software (version 2.50; Perimed AB).

Systolic and diastolic blood pressure were recorded at 5-minute intervals throughout each trial using an automated sphygmomanometer (Boso-Medicus PC; Bosch & Sohn, Jungingen, Germany) on the contralateral upper arm. Mean arterial pressure (MAP) was calculated (MAP = [(2 × diastolic) + systolic]/3) and subsequently used to determine cutaneous vascular conductance (CVC = SkBF/MAP). Cutaneous vascular conductance was identified as the primary outcome measure to ensure that we took variability in blood pressure between testing sessions into account.[17]

We calculated SkBF by averaging values over 20 stable minutes during baseline and during the final 10 minutes (the plateau) of local heating. After heating was started, initial peak and nadir CVC values were assessed over a stable 60-second period, with the initial peak identified as the highest value and the nadir as the lowest value during the first 5–10 minutes of local heating. As is typical with this type of thermal provocation test, a clear nadir was not detected in all participants. In those individuals (~10%), we used data from a 60-second period taken 1 minute after the initial peak. This value was always lower than the initial peak.

Statistical Methods

Data (resting baseline, initial peak, nadir, and plateau) were analyzed using a 2-factor general linear model (time × condition). The response to heat was analyzed using a 3-factor general linear model (time × condition × heat). All data are reported as mean ± SD unless otherwise stated, and statistical significance was assumed at $P \leq .05$. Statistical analyses were performed using SPSS (version 17.0; SPSS Inc, Chicago, IL) software.

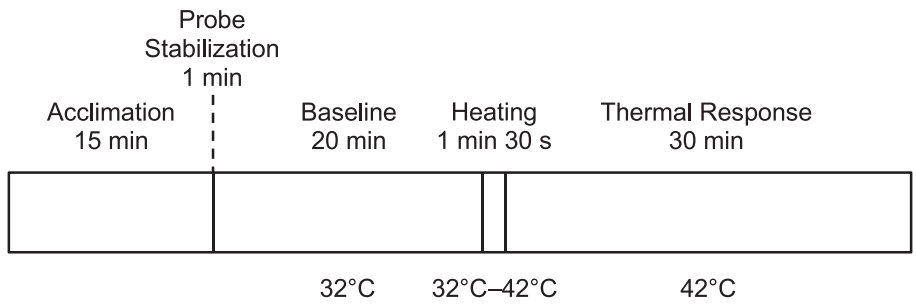

Figure 2. Protocol schematic depicting stages of each trial, with corresponding durations and heating temperatures.

Table 2. Forearm Skin Responses at Resting Baseline and During Local Heating in the Taped and Nontaped Trials in Healthy Participants (N = 13)

Variable	Trial, Mean ± SD				Analysis of Variance *P* Values[a]		
	Taped		Nontaped				
	Taped	Control 1	Nontaped	Control 2	Time	Condition	Time × Condition
Resting baseline							
Skin blood flow, PU	12 ± 8	13 ± 9	10 ± 4	10 ± 6	NA	NA	NA
Mean arterial pressure, mm Hg	76 ± 6	NA	77 ± 5	NA	NA	NA	NA
Cutaneous vascular conductance, PU/mm Hg	0.16 ± 0.06	0.17 ± 0.13	0.13 ± 0.10	0.14 ± 0.09	NA	NA	NA
Local heating							
Initial peak							
Skin blood flow, PU	101 ± 62	98 ± 37	99 ± 37	105 ± 39	.96	.76	.67
Cutaneous vascular conductance, PU/mm Hg	1.28 ± 0.77	1.27 ± 0.50	1.20 ± 0.57	1.37 ± 0.43	.92	.99	.69
Nadir							
Skin blood flow, PU	85 ± 58	83 ± 34	74 ± 35	89 ± 29	.91	.64	.43
Cutaneous vascular conductance, PU/mm Hg	1.09 ± 0.72	1.06 ± 0.44	1.18 ± 0.48	1.17 ± 0.42	.91	.97	.48
Plateau							
Skin blood flow, PU	112 ± 67	104 ± 33	105 ± 45	115 ± 28	.89	.78	.48
Cutaneous vascular conductance, PU/mm Hg	1.41 ± 0.81	1.31 ± 0.40	1.39 ± 0.62	1.51 ± 0.39	.57	.90	.66

Abbreviation: NA, not applicable.

[a] Refers to time (resting baseline, initial peak, nadir, plateau) and condition (taped, nontaped).

RESULTS

All 13 participants completed both trials.

Baseline Measures

Neither baseline SkBF nor CVC demonstrated a main effect of time or condition or an interaction of time × condition ($P > .05$; Table 2).

Local Heating

Local heating induced a typical pattern of an initial peak, nadir, and subsequent plateau in SkBF, which was demonstrated for all trials. No main effects of time or condition or interaction of time × condition were evident for SkBF or CVC at the initial peak, the nadir, or the plateau during heating between trials or measurement sites ($P > .05$; Table 2).

A main effect of heat for CVC was evident during the 30-minute heating protocol ($P \leq .05$), indicating an increase in CVC in response to local heating to 42°C for all experimental trials. No interaction occurred for time × condition × heat in CVC during the 30-minute heating protocol ($P > .05$; Table 3).

DISCUSSION

The 2 major novel findings from this study were (1) no SkBF response was identified between the trials (T versus NT) or measurement sites (taped and collateral areas) at baseline or during local heating and (2) subdivision of the heating phase into neural and NO-mediated elements did not demonstrate differences in SkBF responses between the trials. Therefore, the present findings indicate that KT did not induce SkBF changes through neural or endothelial pathways.

The lack of difference in SkBF responses is in agreement with the results of previous studies undertaken in a healthy population.[14–16] Although Kase et al[14] suggested that KT application enhanced peripheral blood flow in participants with "chronic disorders and poor circulation," no increase was identified in "healthy" participants. These findings are supported by Stedge et al,[16] who noted that KT did not have any effect on cutaneous red blood cell flux in a heterogeneous population. Furthermore, Miller et al[15] measured SkBF, expressed as the percentage change from baseline values, and found no increase in SkBF in healthy participants. Nevertheless, the study's comparison of 2 taping applications (KT versus athletic tape) does not allow a direct comparison with our results. It is possible that the KT application process was a causal factor of the identified SkBF response,[14] which was reportedly within 10 minutes of KT application. The application of KT requires activation of heat-sensitive glue to achieve optimal adherence with the skin[1]; activation is achieved by rubbing along the length of the KT, effectively inducing heat friction. It is, therefore, plausible that the effects observed by Kase et al[14] were actually induced by stimulation of the skin through the heat activation during the application process rather than a direct physiologic response mediated by the KT. During the baseline period of our study, we identified no SkBF response, between either trials or measurement sites, suggesting that any influences from adhesive activation were removed by including a 15-minute acclimation period, which allowed the skin to normalize after the application process.

To our knowledge, we are the first to undertake a comprehensive assessment of the potential SkBF effects of KT application. Additionally, we provide novel data aimed at elucidating the mechanisms through which KT may exert effects on SkBF. The study focused on the potential for an endothelial-dependent vasodilatory mechanism; the biphasic response was investigated specifically to assess whether KT induced an NO or neural response. The stimulation of cutaneous mechanoreceptors associated with the proprioceptive benefits of KT reported in previous studies[10,11] suggested that neural activation of the

Table 3. Forearm Skin Responses at Resting Baseline and In Response to Local Heating[a,b]

	3-Way Analysis of Variance *P* Values						
Variable	Time	Condition	Baseline	Time × Condition	Time × Baseline	Condition × Baseline	Time × Condition × Baseline
Resting baseline							
Skin blood flow, PU	.18	.70	.22	.85	.59	.29	.30
Cutaneous vascular conductance, PU/mm Hg	.13	.69	.26	.83	.52	.27	.32
	Time	Condition	Heat	Time × Condition	Time × Heat	Condition × Heat	Time × Condition × Heat
Heating							
Skin blood flow, PU	.91	.85	.00[b]	.51	.89	.60	.39
Cutaneous vascular conductance, PU/mm Hg	.73	.83	.00[b]	.52	.63	.57	.46

[a] 3-Way analysis of variance refers to (i) time (resting baseline, initial peak, nadir, plateau), condition (taped, nontaped), and baseline; (ii) time (resting baseline, initial peak, nadir, plateau), condition (taped, nontaped), and heat.
[b] Significant heat effect ($P \leq .05$).

endothelium may be greater after KT application. However, we found no difference in either the NO or neural component of the biphasic response between trials (T and NT) or among taping sites (T, NT, CON1, and CON2), indicating that KT did not enhance SkBF via either mechanism in a young healthy population. The effects of KT on those with microcirculatory impairments remain unknown; although Kase et al[14] identified an increase in the volume of peripheral blood flow in such participants (N = 5), the meaning of these findings is unclear due to the lack of robust methods. Furthermore, the authors did not suggest how KT may be used as a treatment modality in such populations or comment upon whether long-term use of KT is feasible.

Our findings agree with those reported previously, but prior research into the effects of KT[14–16] has involved suboptimal methodologic approaches. The very small heterogeneous participant populations in previous studies (N = 9[14] and N = 10[15]) did not conform with guidelines for rigorous vascular assessment[17,19,25]; analyzing males and females together likely confounded the SkBF results.[19] Because no previous authors have undertaken a satisfactory study design and appropriate methods, no suitable data were available to generate sample-size estimations for our study, and therefore, we report preliminary data to inform future researchers. However, there were no trends in *P* values or data in our study of 13 adolescent males. One other study[16] had a larger sample size (N = 61) but was likely underpowered due to the lack of a robust SkBF measurement protocol. First, the methodologic detail provided for the LDF protocol was scant, so it would be impossible for other investigators to replicate the methods and the findings. Second, key confounders of SkBF were not addressed. The skin vasculature is particularly sensitive to small changes in temperature, dietary intake, circadian variations, and hormonal fluctuations. Unless such confounders are tightly controlled within the experimental design,[17,19,25] data are meaningless and cannot be extrapolated, yet no previous authors[14–16] have attempted to control for these well-known confounders of basal SkBF. Third, only basal SkBF data, in arbitrary perfusion units, were reported by Stedge et al,[16] and in 2 studies,[14,15] the unit of measurement was unclear. Best-practice guidelines recommend that data be expressed as CVC data and as a percentage of maximal dilation to account for fluctuations in basal flux and blood pressure. Finally, none of the previous investigators adequately described or justified their taping techniques, making cross-study comparisons difficult. As a result of these reporting inadequacies and violations of best practice, the validity of these previous results cannot be determined.

We applied Kinesio Tex Gold tape, which is regarded as the "original" KT[1] and allows for a more accurate comparison of our findings with the limited research currently available.[14–16] The technique of KT application varies according to the clinical need and the manufacturer's guidelines; when applied in accordance with these guidelines, the mechanism by which KT purportedly achieves an enhanced circulatory response is a "space-correction lifting effect" as a result of "convolutions" formed on the skin.[1,16] This implies that baseline SkBF should be upregulated during taping. However, 2 previous groups[14,15] did not describe the taping techniques that were used, the resistance applied, or the length of time the tape was in position. A third group[16] placed 2 strips of tape proximal to distal on the gastrocnemius muscle but did not document the resistance of the tape and length of time it was in position. We followed recommendations in tape application aimed at facilitating circulation,[1] yet we saw no effects on SkBF at baseline or after the local heating protocol. The degree of KT stretch used in our study was in accordance with the manufacturer's recommendations; stretch (or tension) is reportedly a critical factor to successful KT application, with excessive stretch thought to diminish any reputed effects.[1] A "space-correction" technique uses a 25%–50% stretch,[1] which would appear compatible with the KT application in our study; a 35% stretch was applied, comprising a 10% manual stretch in addition to the reported 25% stretch applied to the tape during manufacturing. However, it is unclear whether the 25%–50% stretch suggested is in addition to the 25% already applied to the KT, which demonstrates the ambiguity associated with KT application and the need for further scientific evaluation.

Limitations

The major limitation of our study was that the same sites were measured in 2 testing sessions, which can result in interday variability.[30] Although standardizing the measurement sites reduced the spatial variation in the dermal vasculature, temporal variations in SkBF may have influenced the data. However, performing 2 trials per participant on the same day would have been impractical due to the need for rigorous control of factors such as dietary intake, diurnal variation, and ambient room temperature.[17,25] As our study was limited and focused on a young athletic population, our findings are therefore generalizable only to this population.

Future Research

Based upon the current findings, it is unlikely that KT application will facilitate tissue healing by enhancing SkBF. However, although we used robust methods to assess the effect of KT on SkBF responses in healthy, trained adolescents, we are unable to comment upon the possible effects of KT application on SkBF in populations with circulatory dysfunction or more importantly, tissue damage or injury. Furthermore, it was beyond the scope of this study to investigate the effects of KT on conduit artery or muscular blood flow; as such, we cannot rule out the possibility that KT may enhance blood flow in other vascular beds.

CONCLUSIONS

Our findings enhance the collective scientific understanding of KT, specifically that it did not appear to augment SkBF in healthy participants through neurogenic or endothelial-dependent vasodilatory mechanisms. Furthermore, the comprehensive approach taken in this study provides a foundation for future research, which is integral to ensuring that sports medicine practitioners use KT appropriately in order to optimize the potential therapeutic benefits for their clients.

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