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How effective the integration of "KAATSU" into different applications in sports medicine? A Review

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Abstract
"KAATSU", a Japanese name renowned as "added pressure," is a patented, novel exercise method that restricts the blood flow to the muscle by applying moderate compression. This study aims to review the impact and the relevancy of integrating KAATSU into sports medicine. Based on the comprehensive studies concerning the guideline of PRISMA, the electronic databases of PubMed Central (n=178), Science Direct (n=14), Springer Link (n=2), Cochrane Library (n=19), and Google Scholar (n= 291) were followed by manual screening method using the keywords of "KAATSU," "sports medicine," "muscle strength" and "hypertrophy" to obtain articles related to the topic. After removing duplicates, the total number of 291 articles were screened again and the remained articles were re-screened for the aforementioned keywords. Finally, 21 articles were included and in conclusion this indicates KAATSU s a safe and promising exercise method for the improvement of skeletal muscle mass, strength, and endurance capacity in healthy, elderly and populations with specific disease conditions.

Keywords: KAATSU, Hypertrophy, Muscle Strength, Rehabilitation, Sport Medicine

1. Introduction
KAATSU Training was firstly introduced in 1966 by Dr. Yoshiaki Sato in Tokyo [1]. The KAATSU training is a method of muscle training performed to reduce blood supply to the muscles by a specially designed belt (KAATSU belt) [1]. KAATSU is generically described as Blood Flow Modification (BFM) by Japanese physicians as the purpose of the use of KAATSU air band is to modify the blood flow. The stretchable KAATSU Air Bands are designed to reduce venous flow without occluding the arterial flow (blood flow to the limbs). It is different from blood pressure cuffs that are specifically designed to occlude (cut off) blood flow to the limbs [1]. The width of the Band is also more distinguishable than a blood pressure cuff (i.e., to avoid arterial flow occlusion). Furthermore, walking, running, cycling, callisthenic exercises, physical therapy, swimming, throwing, pulling, pushing, or any specific movements required in sports or fitness will not be restricted by wearing the KAATSU Air Bands as it precisely controlled by the KAATSU monitoring units (e.g., KAATSU Nano, KAATSU Master 2.0, and KAATSU Wearable) [2].
In the year 1994, Sato was able to apply for his first patents of KAATSU band in Japan (Patent No. 2670421), Europe (UK, Germany, France, Italy with 94206403.0), and USA (Patent No. 6149618) as he began to manufacture and commercialize the first KAATSU bands all round in Japan [1].
In 1995 conscientious academic study and medical research on KAATSU began at the University of Tokyo by transforming the several factors of traditional athletic training, speed of rehabilitation, and recovery. After decades of experimenting, it was proved the improvements in blood circulation and increased hormonal production, especially Growth Hormone (GH) [1], [3], [4], GH stimulates the liver to secrete Insulin-like Growth Factor-1 (IGF-1), which may enhance the function of endothelium and insulin sensitivity [5]. KAATSU encourages even short-term and low-intensity exercise such as walk training, which can induce muscle strength, and increased muscle mass [3], [6-10].
Thus, KAATSU training has become a widely used sports medicine in healthy subjects and athletes and has also been applied to various conditions such as orthopedic diseases, diabetes, and obesity. Furthermore, it has been used as a sports medicine by the USA Winter Olympic Team in 2014, the military of the USA, and in 2016 among athletes at the Rio Olympic Games. KAATSU is a training method that has its expansion over 49 countries in Europe, Asia, North America, South America, Africa, and Oceania by Mount Everest climbers and English Channel swimmers as well as paraplegics [11].

Despite its records on usage in KAATSU Training, there is the available information on the comparative impact of KAATSU Training on the care and management of sports injuries. Therefore, this review focuses on the effectiveness of integrating KAATSU Training with sports medicine.

2. Methodology

In the first phase, a comprehensive literature search was carried out in the following databases: PubMed Central (PMC) ® (U.S. National Library of Medicine, USA), Science Direct © (Elsevier B.V), Springer Link © (Springer Nature Switzerland AG), Cochrane Library © (John Wiley & Sons, Inc.), and Google Scholar. The keywords were "KAATSU," "Hypertrophy," "Muscle Strength," and "Sports Medicine," and articles that were published in English were selected for the study.

The literature search using the above search criteria identified the following number of articles in the respective databases; PubMed Central (n=178), Science Direct (n=14), Springer Link (n=2), Cochrane Library (n=19), and Google Scholar (n=291). After removing duplicates and shortlisting the total number of 21articles were collected to be included in the present review. From the selected 21 articles, 18 are experimental designs, 2 are case studies, and 1 is a pilot study. The articles were firstly selected by viewing the topic by a reviewer (VA). Then the selected papers were again checked by reading the full text by two reviewers (SM and AP) independently. Further, a manual search was performed using the reference list of the included articles to obtain more data. When possible, follow-up on the citations of the studies was done during the literature review and checked whether it is possible to include them. In the final selection of the article's information related to KAATSU training, BFR, KAATSU exercise, and KAATSU Rehabilitation were strictly followed. The studies that meet the inclusion criteria of being English articles published based on the research done to examine the influence of KAATSU training on sports medicine were included. The rest of the articles were excluded at these stages.

3. Results

KAATSU training can induce a variety of beneficial effects such as increased muscle mass, muscle strength, and a number of facilities has adopted it in recent times. The results obtained from a variety of studies show that the most popular purpose of KAATSU training is to strengthen the muscle in athletes and promote the health of subjects. The beneficial effects also include the elderly, which can be identified as a compromising benefit of KAATSU training. Furthermore, the results of the reviewed studies show that this method has also been applied to various kinds of physical conditions, cerebrovascular diseases, orthopedic diseases, obesity, cardiac diseases, neuromuscular diseases, diabetes, hypertension, and respiratory diseases. Various types of exercise modalities (physical exercise, walking, cycling, and weight training) have been used under different protocols of KAATSU training when examining the effect of KAATSU. Most facilities have used 5-30 min KAATSU training each time and performed it1-3 times a week. The prominent characteristic that can be observed in the studies we reviewed was, approximately 80% of them were satisfied with the results of KAATSU training, with only small numbers of complications reported. The incidence of side effects was as follows; venous thrombus, pulmonary embolism, and rhabdomyolysis. The results included in the following table in detail indicate that the KAATSU training is a safe and promising method for training athletes and healthy persons and can also be applied to persons with various physical conditions. Furthermore, it shows that under the guidance of appropriate KAATSU training leaders or instructors, safe and beneficial effects can be achieved, regardless of subject age, gender, or physical condition.

The table below demonstrates the main findings and the conclusion detailed in the selected studies with their specific study population and KAATSU training protocol (Table 1).

Table 1: Summary of reviewed literature

Study population	KAATSU Training or testing protocol	Main Finding	Conclusion	Reference
A healthy young male person (n=1)	Symptom-limited graded exercise testing with the aid of a cycle ergometer on 2 days separated by 1 week of an interval with KAATSU and without KAATSU	• With lower perceived and physical effort, the participant reached AT with KAATSU than without KAATSU • Just below AT, muscle activation remains unchanged during exercise between with and without KAATSU.	A comparative study of with KAATSU and without KAATSU exercise just below AT with lower physical and without perceived effort does not cause any difference in muscle activation. Therefore, low-intensity aerobic exercise with KAATSU is believed to be a low-burden, effective and safe method in the rehabilitation of cardiac patients.	[12]
Male track and field college athletes (n=15)	The KAATSU group was provided with training of twice daily with leg curl and squat exercises (20% of 1-RM, 3 sets of 15 repetitions). This was continued for 8 consecutive days while both KAATSU and control groups were involved in the regular jump/sprint training sessions	• The muscle-bone CSA, quadriceps, hamstrings MTH and leg press strength were increased by 4.5% (p0.05), ($p<0.01$) 5.9%, 4.5% and (9.6%, $p<0.01$) respectively in the KAATSU group. • Overall, 30-m dash times improvement of ($p<0.05$) in the KAATSU-training group is observed with a significantly improved ($p<0.01$) initial acceleration phase (0-10m) • None of the jumping performances were improved ($p>0.05$) in both groups	KAATSU-training can be identified as an effective method capable of performing together with regular-season training in enhancing muscle hypertrophy without a loss in performance.	[13]
Subjects (10 males and 6 females with previous experience in the practice of recreational strength training for minimum 12 months (n=16)	Traditional Strength Training and KAATSU Strength Training	• Greater loss of peak torque resulted from the KAATSU method and its recovery was found to be better at 24 and 48 hrs after the intervention with a peak torque peak versus the Traditional method. • A more significant asymmetry and a higher fatigue index is observed in the KAATSU method versus the traditional method.	An increase in the concentration levels of LDH, CK, and lactate was promoted under the KAATSU training method, in addition to presenting higher values of peak torque and fatigue index.	[14]
Healthy young men (n=18)	Walk-training with KAATSU (restricted venous leg muscle blood flow) was continued for 3 weeks and 6 days per week, two times a day, using five sets of 2-min bouts (treadmill speed at 50 m/min) and only 1-min rest was allowed between bouts.	• Elevated Serum GH was observed ($P < 0.01$) after acute KAATSU-walk exercise but not in control-walk training. • CSA of thigh muscle and muscle volume was increased by 4-7%, and 8-10% elevation was seen in 1-RM along with maximum isometric strength elevation in the KAATSU-walk group • Muscle size, dynamic, and isometric strength remained without a change in the control-walk group. • CK and myoglobin which are the indicators of muscle damage with greater specificity, and resting anabolic hormones were not changed in both groups.	Slow-walk training combined with leg muscle blood flow restriction induces muscle hypertrophy and improves strength gain, in spite of the minimal level of exercise intensity. KAATSU walk training may have the needed potential to be a helpful method in promoting muscle hypertrophy. This method is approachable to a wide range of the population, including the elderly and frail.	[9]
Young men (n =12)	Walk training was done on a motor-driven treadmill KAATSU at the speed of 50 m per min for five 2-min bouts, with only a 1- min rest between bouts and was continued for 3 weeks, 6 days per week at a frequency of once per day.	• Quadriceps, hamstrings muscle volume, 1-RM leg press, leg curl, and isometric knee extension strength was increased by 1.7 ($P<0.05$), 2.4% ($P<0.05$), 7.3 ($P<0.05$), 8.6% $P<0.05$) and (4.4%; $P<0.01$) respectively, following KAATSU-walk training. • Knee flexion strength increase by 1.7% was not elevated following KAATSU walk training.	Within a compressed training duration, the impact of KAATSU-walk training on muscle size and strength has the ability to accomplish a large number of training bouts. There maybe an association between frequency-dependent muscle enlargement with KAATSU-walk	[15]

			training	
400m sprint athletes (n=23)	400 M sprinting training with KAATSU training was conducted for 10 weeks, 3 days per week, and once per day at (65% - 85%) from the maximum intensity of pulse with the use of a polar watch	• Significant differences between the experimental group and the control group were observed in post-exercise muscle volume and plasma PGE2. • Significant variations were seen in the sprinting times by (3.48%) after the program for the group under KAATSU training but no difference in back strength.	KAATSU training causes both muscle hyperplasia and hypertrophy	[16]
A 47-year-old male with previous resistance training and aerobic training experience (n=1)	LIT with KAATSU was continued twice per day and for 7 consecutive days.	• After 7 days of training, KAATSU training resulted in an elevation by 3.1% in muscle-bone CSA • Both muscle volume and Q-CSA max began increasing after the first day of KAATSU training and continued to be raised for the rest of the training period. • Following 7 days of KAATSU resistance training, the Q-CSA max and muscle volume increase by 3.5% and 4.8%, respectively, was seen. • Elevation in isometric knee extension strength per unit Q-CSA max was observed after training. • After a single bout of KAATSU training exercises on the very first day of the training, slight increases in CK and myoglobin were observed, but the values were returned to normal levels 2 days after the training. • IL-6 did not subject to changes throughout the training period	For the rapidly induce skeletal muscle hypertrophy and strength hypertrophy KAATSU can be suggested as a safe and effective method as the subject gained the above results after one week of LIT-KAATSU training.	[17]
Healthy men (n=16)	LIT-KAATSU was conducted twice per day with an interval of at least 4 hours between sessions) and was continued for 12 consecutive days.	• Elevation of 17% and 23% in squat and leg curl respectively in 1-RM strength in the LIT-KAATSU, and this was higher than those of the LIT (9% and 2%) • Muscle bone CSA and circulating IGF-1 (Both $p<0.01$) was gradually increased in the LIT-KAATSU. • Muscle volume in biceps, quadriceps, femoris and gluteus maximus were increased by 10.1%, 7.7%, and 9.1% respectively, under LIT-KAATSU ($p<0.01$) and 1.9%, 1.4%, and -0.6% under LIT. • Relative strength between post-testing and baseline remained unchanged ($p>0.05$) in both groups	After two weeks of the LITKAATSU training session, skeletal muscle strength gain and muscle hypertrophy were increased.	[5]
Qualified football players (n=18)	Strength exercises under KAATSU Training	• Significantly higher results in strength endurance were represented after 26 days from the start of strength training with KAATSU	The significant changes in strength endurance that occurred after 7 days from the termination of KAATSU Training may be associated with the accumulation of energy substances in muscle fibers and an improvement in capillarization.	[18]
Males (n=12)	Low-intensity (20% 1- RM) with KAATSU).	• For the parameters such as PVA, MVC, EMG amplitude, MMG amplitude, EMG MP and MMG MPF no main effects or significant interactions were observed for time or session for pre-and post-exercise isometric MVCs, with and without KAATSU. • Significant increase in the average normalized EMG amplitude from repetitions 1-4 to 5-8 to 9-12 and elevation in MMG amplitude significantly from set 1 to 2 for both the KAATSU and no-KAATSU sessions.	With or without vascular restriction, intermittent isometric contractions at 20% 1-RM significant muscular fatigue is not caused as the intensity is not sufficient.	[19]
Healthy subjects (n=40)	The chosen exercise group performed 3 sets of 15 repetitions of unilateral bicep curls and triceps extensions lifting loads equivalent to 20% of their predetermined maximal strength with a pneumatic cuff on one arm (CUFF) and without any on the other (NCUFF). The control group did not perform any exercises but wore the cuff on one arm for a	• Compliance recorded for the exercise and Control groups were 85.4% and 97% respectively. • 85.4% of the provided workouts were completed by Exercise subjects while controls attended for 90.4% of their sessions. • Pressure (moderate; 3.2 +0.6) followed by aching (weak; 1.7 +0.4) was the prominent sensation reported in the arm with the CUFF. • Ratings of perceived exertion were higher for the CUFF (3.2 +1.0, 5.1 +1.8, and 7.0 +2.5) versus NCUFF (1.5 +0.3, 2.4 +0.3, and 3.3 +0.4) arm for sets 1, 2, and 3, respectively	KAATSU training is well tolerable by those who are performing it and can be considered as a viable alternative to conventional resistance exercise.	[20]

	time comparable to the exercise group			
Healthy aged females (n=10))	In the supine position 3 sets of 15 repetitions of unloaded unilateral knee extension exercises with KAATSU.	• The exercise which was done without KAATSU did not induce alterations in mass and velocity without any alterations in the blood flow throughout the entire exercise series but exercise with KAATSU induced an increase (P<0.05) in blood flow owing to its elevation in velocity. • During the intervals between these exercise sets, increases were not eliminated. • Elevation in HR (P<0.05) was observed with the second and third sets of exercises which were done with KAATSU, when compared with HR before the initiation of exercises. • In hematocrit and blood lactate, no changes were found in both types of exercises. • NE was raised (P<0.05) at the completion of the exercise sets.	Increased forehead cutaneous blood flow is due to the unloaded knee extension exercise with KAATSU. HR increased owing to the elevation of NE in response to exercise with KAATSU, and this should have possibly influenced by modulation of cutaneous circulation dynamics.	[21]
Male patients with stable IHD (n=7)	For three months, two times per week, resistance exercises (leg press, leg curl, and leg extension) were conducted with a KAATSU belt on femoral muscle.	• Low-intensity KAATSU resistance training resulted in a significant rise in the leg curl (18%), leg press (15%) and leg extension (17%) 1-RM strength • Hamstring and adductor CSA were also elevated by LIKRT • Significant elevation in VO2AT and VO2peak by 10.9% and 10.7% was observed respectively under LIKRT • IGF-1 and hsCRP were not altered either before or after the training.	LIKRT has been identified as an effective resistance method in cardiac rehabilitation which is successful in increasing muscle mass and endurance capacity in patients with IHD.	[22]
Recreationally active male (n=5)	Leg exercises (squat and leg curl), arm (arm curl and triceps press down) with KAATSU on separate days	• Immediately after and 15-min after exercise for LA significant elevations were observed. Furthermore, at immediate post, 15- and 60-min after exercise in both arm and leg exercise raised GH levels were recorded. • After doing exercise for NA in both leg and arm significant elevations were observed, but greater in NA than arm was resulted in leg exercise at immediately post-exercise • The difference was not found between change in plasma volume after exercise and two exercises	Responses due to the GH secretions when exercising may be similar between the leg and the arm when conducted at equivalent exercise intensity and under the restriction stimulus	[23]
Normal healthy adult males (n=16)	Thirty repetitions for 2 to 4 sets until fatigue for bilateral leg extension-flexion exercise (20% of 1 RM - Proteus Multi Exercise Machine) with KAATSU Training belt at the proximal ends of both legs	• Significantly raised GH levels were observed with Short-term low-intensity resistance exercise with KAATSU, compared to STLIRE without KAATSU • When compared to the control condition, maximal blood pressure and heart rate HR in STLIRE with KAATSU were higher • When compared to the controlled condition, Stroke volume was lower due to a drop-down in the venous return induced by KAATSU training • A significant change in total peripheral resistance was not found. • The elevation in lactate and NOR in STLIRE with KAATSU was also considerably higher than without KAATSU	For the rehabilitation of cardiac patients or individuals with low physical fitness, KAATSU training may become a unique method	[24]

Young male bodybuilders and power-lifters (n=6)	Low-intensity (approximately equal to 50% 1RM) exercise with slow movement and tonic force generation (3 seconds for lowering and 3 seconds for lifting actions, 1-second pause, and without a relaxing phase; LST), low-intensity [~30% of 1-RM exercise with LO-KAATSU, low intensity (same as LST) isometric exercise at 45 degrees knee angle (ISO), and high-intensity (approximately equal to 80% 1RM) exercise with normal movement speed (HN)	• During and after LO-KAATSU largest changes in the muscle oxygenation level measured was shown with near-infrared continuous-wave spectroscopy. • Among the four exercise regimens minimum oxygenation level was observed during the LO-KAATSU. • The largest elevations in the muscle oxygenation after LO-KAATSU were among the four regimens. LST and HN were markedly (P < 0.05) higher than those after ISO • No significant differences were among those after HN and LO-KAATSU.	"KAATSU" resistance exercises are capable of marked changes in circulating growth hormone and muscle oxygenation level, both of which may be related to muscle hypertrophy	[25]
Healthy subjects (n=40)	The chosen exercise group performed 3 sets of 15 repetitions of unilateral bicep curls and triceps extensions lifting loads equivalent to 20% of their predetermined maximal strength with the pneumatic cuff on one arm (CUFF) and without a	• In the exercise group, bicep curl (17.4% +4.1% and 18.7% +4.9%) and triceps extension (15.8% +3.4% and 10.7% +2.7%) strength raised significantly for both the CUFF and NCUFF arms, respectively • In strength between the CUFF and NCUFF arms within the group no	Muscle CSA and muscle strength can be increased by KAATSU training	[26]

	CUFF on the other (NCUFF). The control group did not perform any exercises but wore the cuff on one arm for a time comparable to the exercise group.	significant differences were occurred. • In the control group for the CUFF and NCUFF arms no strength changes were noted. • Significant elevation in the arm girth and muscle CSA was observed in the exercise group compared to the control subjects		
A 67-year-old female (n=1)	Walked at speed 0.85 m per second for five 2-min bouts with only 1 min of rest between bouts, for 8 weeks with five times per week wearing the KAATSU cuff	• Six Minute Walk Test, Ten Meter Walk Test, Timed Up and Go and lower extremity strength measures, raised by 18.2% up to 46.8% from baseline to post-test	Combination build among KAATSU with a slow-speed walking program increases its performance on impairment assessments of the lower extremities and functional activity measures.	[27]

Young men (n=5)	LIT-KAATSU was performed by 3 men (age 20-47 years) and LIT alone by two men (age 23 and 27 years).	• After two weeks of the training mean relative change in 1-RM squat strength was 14% in the LIT-KAATSU and 9% in the LIT. • Mean changes in quadriceps muscle CSA were 1.8% for LIT and 7.8% for LIT-KAATSU. • Changes in muscle fibre CSA was 27.6% ($p<0.05$) for type-II and 5.9% for Type-I and in the LIT-KAATSU, and - 2.1% and 0.5%, respectively, in the LIT. • Mean fibre CSA changed 17.0% in the LIT-KAATSU, but not in LIT (-0.4%)	After a high-frequency KAATSU training period for two weeks' skeletal muscle and fibre hypertrophy, especially of the type-II fibre, was increased.	[28]
Healthy college students (n=12)	Four sets (30, 15, 15, and 15 reps) of flat bench press exercise was conducted under two different conditions with KAATSU and without KAATSU (30% of a predetermined 1-RM) was performed.	• iEMG was gradually increased in both TB and PM muscles for the KAATSU condition during all 4 sets of the exercise. • In iEMG in the TB and PM muscles the magnitude of the increase was higher with KAATSU. • In the first set, the mean exercise intensity from normalized iEMG was approximately 40% of 1-RM in both KAATSU conditions and Control. • The mean exercise intensity of both muscles were 60 to70% of 1-RM for the KAATSU condition and only about 50% of 1-RM was observed for the Control condition, during the fourth set.	iEMG elevation in the trunk muscle during KAATSU might be an essential factor for KAATSU training-induced trunk muscle hypertrophy	[29]
An 84-yearold woman (n=1)	For over 24 weeks, a total of 48 sessions of KAATSU resistance training were provided. Both the training intensity and volume were set at 20% or 30% of 1-RM with 75 repetitions for knee extension and leg press exercises, respectively.	• 1-RM strength, quadriceps muscle CSA and chair-stand test raised throughout 24- week training period • Bodyweight, haemodynamic parameters (except for systolic blood pressure), were remained unchanged. Arterial compliance coagulation system and muscle damage continued to happen throughout the training period	In older adults, KAATSU resistance training may be a highly effective and safe training method for the improvement of skeletal muscle mass.	[30]

(AT Anaerobic Threshold, CSA Cross-Sectional Area, MTH Mid-thigh muscle thickness, GH Growth Hormone, CK Creatine kinase, 1-RM Maximal dynamic strength, LIT Low-intensity resistance training, Q-CSA max Maximum quadriceps muscle, IL-6 Interleukin-6, IGF-1Insulin growth factor-1, LDH Lactic Dehydrogenase, PGE2 Plasma Prostaglandins, PVA Present voluntary activation, MVC Maximal voluntary contractions, EMG Electromyogram, MMG Mechanomyography, MPF Mean power frequency, HR Heart Rate, NE norepinephrine, NA noradrenaline, IHD Ischemic Heart Disease, LIKRT Low-intensity KAATSU resistance training, VO2 Maximal Oxygen Consumption, hscrp high-sensitive C-reactive protein, LA Blood lactate, STLIRE Short-term low-intensity resistance exercise, LO-KAATSU Low-Intensity KAATSU, TB Triceps brachii, PM Pectoralis major, iEMG integrated Electromyogram)

4. Discussion

This review includes the influence of KAATSU training on muscle strength, mass and endurance capacity in individuals and its applicability in sports medicine. The selected 21 articles revealed the association of KAATSU training and its effects.

One of the highlighting outcomes of KAATSU training is the gaining of significant and rapid muscle hypertrophy similar to the results given from high-intensity training [15]. Under the effect of KAATSU, both the cross-sectional area of the muscle and muscle strength has been increased [26]. Furthermore, a significant increase was observed in the cross-sectional area of the type II muscle fibers in a study done among young men after conducting a two weeks training session with KAATSU [28]. Even though, the underlying mechanism of achieving the aforementioned is not yet completely understood, the Growth Hormones (GH), Insulin-like Growth Factor I (IGF-I), and other myogenic regulatory factors are believed to play vital roles in the process of gaining muscle strength, mass and endurance capacity [5].

In a study done to compare the responses of Growth Hormones to an acute resistance exercise after combining it with the restriction of muscular venous blood flow in KAATSU to modify the blood flow in the muscle groups of the arms and legs, it was found out that GH secretory responses to exercise may be similar between the arm and leg when performed at equivalent exercise intensity [23]. KAATSU resistance exercises can change circulating GH and muscle oxygenation levels, while GH promotes skeletal muscle growth and strength [25].

When engaging in seasonal sports, off-season resistance training is considered vital in recovery and training. Even it is of utmost importance, most studies have proven that the time allocated for muscle hypertrophy is not sufficient during the off-season as substantial muscle hypertrophy needs 3-4 months of vigorous resistance training. Under these circumstances, the importance of effective and efficient methods to promote muscle hypertrophy comes forth. With KAATSU, it has been found out that substantial muscle hypertrophy can occur with a training intensity as low as 20% of one repetition maximum [9] and with two weeks of low intensity twice daily KAATSU training [13].

Furthermore, a study done on KAATSU training has been suggested this as an effective and a safe method for the rapid induce of muscle strength and hypertrophy since there was no elevation in the indicators of muscle damage and inflammation during and after the training. Therefore, this can be identified as an advantage over high-intensity training as high-intensity training produces indicators of muscle damage and inflammation in the plasma [17].

In addition to muscle hypertrophy, increased muscle strength is another essential factor to be achieved in sports, and this can be done with KAATSU within a shorter duration and safely. This may be due to increased high phosphate utilization in the hypoxic phase and enhanced mechanical load on the muscle hypertrophy [16].

Physical conditioning is a significant procedure that is carried out with people who engaged in sports. Strength training stands as a leading method of physical conditioning, and KAATSU training has been suggested as a successful alternative as less fatigue and a greater loss of peak torque were noted in the subjects at 24 hours [14]. In strength training, creatine kinase and lactate dehydrogenase which are the main indicators of muscle damage was observed in the bloodstream but with KAATSU due to the greater muscular and metabolic intensity and minimized muscle damage the above indicators were not elevated [9].

A study done on the investigation of acute and chronic effects of walk training combined with KAATSU on muscle size and strength along with hormonal parameters using 18 healthy young men muscle hypertrophy was observed without any changes in the extracellular liquid/tissue content [9]. Aside from muscle hypertrophy and muscle strength the similar metabolic adaptations in skeletal muscles that are taken place in an ischemic muscle have been observed. In a study done with the participation of athletes, it was discovered that they have increased forearm blood flow, increased glycogen synthesis, and maximum total body oxygen volume as the consequences of physical training. Furthermore, in a cross-sectional study, it was revealed that the effect of increased insulin action is a direct stimulatory effect of acute exercise on glucose disposal vanishes within few hours [31]. With KAATSU resistance training, muscle glycogen storages were enhanced [17] and through the comparison of the total maximum oxygen volume in blood during KATTSU walk exercise and 1 – repetition maximum (1 –RM) resistance exercises concluded that, from a metabolic perspective, the intensity of KAATSU- walk exercise is equivalent to the metabolic cost of 10 – 20% RM of exercise [9].

A study done on sprint records (400m) for the first time to demonstrate KAATSU resistance training induce has consistently shown that it increases physical fitness and human performance elements, and great variations were observed in the spring events. Furthermore, in the same study effect of KAATSU resistance training on prostaglandin (PGE2) and protein kinases was investigated and increased PGE2 secretions and protein kinases were observed, and an assumption was made that the hypertrophy may be due to this reason [16].

Strength endurance occupies an important place in sports such as football, wrestling, boxing, basketball, etc. in these types of sports, strength endurance and muscle endurance is highly required, and a study was done with the participation of 18 qualified football players to investigate the influence of KAATSU training on the strength endurance significant changes were observed after seven days after the termination of KAATSU training. Accumulation of energy substances and improvement in capillarization were the changes that led to increased strength endurance [18].

Rehabilitation after sports injury should follow modern rehabilitation protocols under appropriate supervision. Modern sports injury management consists of a team approach involving the sports physician, physiotherapist, strength and conditioning coaches, etc. [32]. In the rehabilitation process, a systematic approach is taken, and isometric exercises are done initially [19]. In the same study, it was reported that the application of vascular restriction in KAATSU, even in the absence of physical exercises, has a positive impact on the skeletal muscle that has undergone atrophy due to immobilization.

Bench press which is also categorized under isometric exercises, has investigated with and without KAATSU to determine the electromyographic responses of arm and chest muscles with the involvement of 12 healthy college students. Through this study they have supported the previous findings of muscle hypertrophy [29].

During physical exercises or when engaged in sports, due to the activation of the sympathetic nervous system, heart rate,

stroke volume, and cardiac output is being increased. When involved in KAATSU training, hemodynamic parameters were altered. The investigations were done on the unloaded knee extension exercise in the presence of KAATSU, particularly stimulate cutaneous circulation in peripheral regions with a significant elevation in velocity of blood flow [21].

In a study done to assess perceived sensation, exertion rates, and compliance to an upper arm with the KAATSU training programme the prominent sensation reported was the pressure followed by aching, and the ratings for the perceived exertion were higher [20].

The underlying mechanism of KAATSU has the potential to increase metabolic stress, which is capable of facilitating hormone production and activating fast-twitch muscle fibers. According to many of the researches done, low-intensity KAATSU resistance training has been identified as a promising and successful method in cardiac rehabilitation as patients with cardiac incapability are more vulnerable to develop either cardiac or respiratory complications at high-intensity exercises. This was achieved after identifying low-intensity resistance training, combined with reduced venous blood flow from the working muscle as an alternative to the high-intensity resistance training [22].

Furthermore, in a study done for 24 weeks to find out the effect of KAATSU resistance training on the size of the femoral muscle and its safety in an 84 years old woman was able to support all the effects caused by KAATSU and this further proved that KAATSU is not only successful in sports medicine but also reliable in treating a wide variety of people belong to different categories [30]. Since this is a low-intensity training exercise, protocols could be applied to patients with cardiovascular diseases, elderly persons, and people who couldn't tolerate high mechanical stress placed on muscle, tendons, and joints [24, 27].

5. Conclusion

KAATSU training is an innovative approach that involves externally applied compression and thereby restricts blood flow to the active skeletal muscles. This effect serves in increasing muscle mass, hypertrophy, and also strength under low resistance training. The significant characteristics of this method are the short time duration it takes to give similar results as with high resistance training but with less effort. Because of these features, KAATSU training has been identified as a simple method of exercise rehabilitation, and especially in "the return to play," a short duration completion can be achieved. In seasonal sports with off-seasons periodization can be efficiently used to regain muscle strength and hypertrophy without affecting performance. In addition to the muscle, rehabilitation can be progressed with KAATSU after injuries. Therefore, this can be considered as a safe, cost and time-effective method that is possible to integrate with sports medicine and also as a method that is applicable to people with cardiac defects, aged people, and many others who cannot engage in high resistance training due to different disabilities.

Based on the available evidences KAATSU is effective in integrating with sports medicine, even though this can be identified as an area where broad studies have not been conducted. According to the studies done so far, the underlying mechanism of increasing muscle mass, hypertrophy, and strength is ambiguous. Therefore, there is a necessity for the future studies on the different applications, side effects and many more aspects related to KAATSU and establishing this with a stable scientific basis is still found.

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