Vascular, Muscular and Autonomic Changes in Response to KAATSU

Dr. Jim Stray-Gundersen, MD
I have been reading, learning and practicing KAATSU Training in the USA for ~15 months.
Dr. Sato has developed a very special form of training.

Josh Saunders
New York City Football Club

Mikaela Shiffrin
Slalom Gold Sochi

Future Kentucky Derby Winner

Ted Ligety
Giant Slalom Gold Sochi
My Findings

- KAATSU is very safe, when done Dr. Sato’s way.
- KAATSU is very effective at improving strength and fitness, when done Dr. Sato’s way.
- KAATSU is very convenient and time efficient, when Dr. Sato’s way.
- KAATSU is difficult to explain
- How do you do KAATSU safely and effectively?
- How do you educate excellent KAATSU Instructors?
- U.S. military, coaches, and corporations need scientifically sound, accurate explanation.
My Questions

• Are researchers who study ischemic or blood flow restriction training, doing KAATSU?
• Are researchers who think they are doing KAATSU, doing it correctly?
• What is the correct way to describe KAATSU?
• What is the best way to show safe and effective KAATSU?
Tools to Explain KAATSU

- **Doppler Ultrasound** to document the arterial and venous blood flow changes.
- **Near Infra Red Spectroscopy** to document the profound disturbance of homeostasis in the exercising muscle from proper KAATSU.
- **Heart rate monitoring** to document the changes in autonomic function from KAATSU Training.
- **High Pressure Liquid Chromotography** to document changes in the Metabolome to KAATSU Training.
Monitoring Setup

**First Beat Body Guard**
Heart Rate Monitor
Accellerometer

**MOXY**
Near Infra Red Spectroscopy
SmO₂
Muscle Oxygen Saturation

**Sonosite MicroMaxx**
Doppler Ultrasound
Arterial and Venous blood flow

**Nelcor**
Pulse Oximeter
SpO₂
Arterial Oxygen Saturation
KAATSU at 48 mmHg (fitting pressure)
56.7 mls/min

This shows the pulse of arterial blood
KAATSU at 100 mmHg
21.8 mls/min

This shows the pulse of arterial blood
KAATSU at 200 mmHg
20.8 mls/min

This shows the pulse of arterial blood

Here we have the patent artery and vein above it
KAATSU at 300 mmHg
13.1 mls/min

This shows the pulse of arterial blood and one can see some retrograde flow.

Here we have the patent artery and vein above it.
With Doppler Ultrasound, we can prove that we:

– Impede, but do not occlude arterial inflow.
– Vasodilate all blood vessels distal to the KAATSU air band.
– Impede and distend the capillary and venous space.
– Change the venous outflow pattern to pulsatile flow in the deep, major veins when the muscle contracts.
Vascular Mechanics of KAATSU

- When the KAATSU band is applied, the venous and capillary space distend.
- Once they have maximally distended, any additional arterial inflow is accompanied by venous outflow. However, this is done when the muscle contracts.
- The effect is one in which the circulation is impeded or slowed such that working muscle does not get the oxygen and fuel it needs to continue to work.
- In addition, metabolic waste products are not cleared, causing disturbance of homeostasis in the working muscle.
Disturbance of Homeostasis in Muscle

**Protocol**
Relaxed Rest
Fitting Pressure (50 mmHg)
25 arm curls
KAATSU 100 mmHg
25 arm curls
Release
KAATSU 200 mmHg
25 arm curls
Release
KAATSU 300 mmHg
25 arm curls
Release
KAATSU 400 mmHg
Arm curls to failure
Release
Muscle proximal (blood flow not limited) to the air band
Not very active in arm curls

No KAATSU
No Exercise

**MOXY**
- Total Hb in muscle
- SmO2

Proximal to cuff—R Deltoid
(not exercising, no KAATSU)

Distal to cuff—R Biceps
(Exercising, KAATSU)

Cuff at Fitting Pressure—L Biceps
(Exercising, but no KAATSU)
Total [Hb] (gms/dl) R deltoid

- No blood flow impediment
- No exercise
Right m. deltid SmO2 (

<table>
<thead>
<tr>
<th>KAATSU</th>
<th>0 mmHg, 25 Arm curls</th>
<th>50 25 a.c.</th>
<th>100 25 a.c.</th>
<th>200 25 a.c.</th>
<th>300 25 a.c.</th>
<th>400 25 a.c.</th>
<th>Arm curls to fail</th>
<th>Recovery</th>
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</table>

No blood flow impediment
No exercise
Air band not inflated  
(blood flow not limited)  
Same exercise as right arm  

No KAATSU  
Exercise  

**MOXY**  
-Total Hb in muscle  
-SmO2  

Proximal to cuff—R Deltoid  
(not exercising, no KAATSU)  

Distal to cuff—R Biceps  
(Exercising, KAATSU)  

Cuff at Fitting Pressure—L Biceps  
(Exercising, but no KAATSU)
Total [Hb] (gms/dl) L biceps

No KAATSU
Arm Curl Exercise (like the right side)
No KAATSU,
Arm curl exercises

Rest

25 arm curls  25 arm curls  25 arm curls  25 arm curls

arm curls to failure on right arm

Recovery Hyperemia
Muscle distal (blood flow limited) to the air band. Very active in arm curls

**KAATSU Exercise**

**MOXY**
- Total Hb in muscle
- SmO2

Proximal to cuff— R Deltoid (not exercising, no KAATSU)

Distal to cuff— R Biceps (Exercising, KAATSU)

Cuff at Fitting Pressure— L Biceps (Exercising, but no KAATSU)
Total [Hb] (gms/dl) R biceps

KAATSU--blood flow impediment
Exercise to failure
Right m. Biceps $\text{SmO}_2 (%)$

- Rest
- KAATSU 50
- KAATSU 100
- KAATSU 200
- KAATSU 300
- KAATSU 400

Recovery
Hyperemia

No Distress
25 arm curls
25 arm curls
arm curls to fail

Some muscle “burn”
Muscle failure!
SmO$_2$ of the time during Arm Curls to Failure at 400 mmHg

Very quickly, these contractions were associated with pain in the active muscle and eventually (~50 reps) led to contraction failure.
Correct KAATSU

• Profound Desaturation in Exercising Muscle
  – Hemoglobin in the working muscle 0-15% saturated with Oxygen
• Profound Reactive Hyperemia post Exercise
• Unable to continue (Muscle Failure)
First Beat Body Guard
Autonomic Function
Heart Rate Variability
Heart Rate
Ventilation
Energy Expenditure
No Bands

Arm Curls: 25-25-25
Hand Grip: 25-25-25
Push Ups: 25-25-25

Double Leg Squats: 25-25-25
Heel/Toe: 25-25-25
R & L Single Leg Squats: 25-25-25

“REAL” KAATSU
410 mmHg arms bands
Arm Curls: 50-30-20
Hand Grip: 50-40-30
Push Ups: 50-30-10

460 mmHg leg bands
Double Leg Squats: 50-30-25
Heel/Toe: 25-25-25
R & L Single Leg Squats: 30-25-20
All exercises to muscle failure

“Inadequate” KAATSU
100 mmHg

Arm Curls: 25-25-25
Hand Grip: 25-25-25
Push Ups: 25-25-25

Double Leg Squats: 25-25-25
Heel/Toe: 25-25-25
R & L Single Leg Squats: 25-25-25
Sympathetic Activation

**Real KAATSU**
Arms 410 mmHg
Legs 460 mmHg
All exercises to failure

**Inadequate KAATSU**
Arms 100 mmHg
Legs 100 mmHg
No exercise to failure

**No KAATSU**
Just exercises
Heart Rate (bpm)

Real KAATSU
Arms 410 mmHg
Legs 460 mmHg
All exercises to failure

Inadequate KAATSU
Arms 100 mmHg
Legs 100 mmHg
No exercise to failure

No KAATSU
Just exercises
Ventilation
L/min

**Real KAATSU**
Arms 410 mmHg
Legs 460 mmHg
All exercises to failure

**Inadequate KAATSU**
Arms 100 mmHg
Legs 100 mmHg
No exercise to failure

**No KAATSU**
Just exercises
Energy Expenditure (Kcals/min)

**Real KAATSU**
- Arms 410 mmHg
- Legs 460 mmHg
- All exercises to failure

**Inadequate KAATSU**
- Arms 100 mmHg
- Legs 100 mmHg
- No exercise to failure

**No KAATSU**
- Just exercises
KAATSU: Training Effect Score 1.6

Endurance Training Classification

Classification of the measurement to different endurance training types.

Sham KAATSU: Training Effect Score 1.8

Endurance Training Classification

Classification of the measurement to different endurance training types.
• Incorrect KAATSU is similar to exercise without KAATSU.
• Correct KAATSU has a much greater sympathetic activation than either incorrect KAATSU or exercise without KAATSU.
• Correct KAATSU has a greater increase in heart rate and ventilation than incorrect KAATSU or exercise without KAATSU.
• Correct KAATSU has higher energy expenditure than incorrect KAATSU or exercise without KAATSU.
• Correct KAATSU stimulates a robust autonomic response.
Human Metabolome
Current day laboratory assessment of metabolic status

$50 -- $100 per assessment
Dr. Robert Gerzsten
Harvard Medical School,
Massachusetts General Hospital
Where to mine for novel pathways and predictors

- nucleotides
- amino acids
- organic acids
- carbohydrates
- lipids

--from Wang & Gerszten Nature 2008
Requires only a drop of blood (100μl)
Targeted Metabolomics Platform

Organic acids, amino acids, nucleotides, carbohydrates, lipids

Metabolite “Address”:
Chromatographic elution time, mass spec characterization
Targeted approach covering major pathways downstream of protein, lipid and carbohydrate metabolism
Reproducibility: CVs (~10-15%)
Sensitivity: low ng/ml
Breadth:
  - ~400 endogenous metabolites
  - ~30 “exogenous” metabolites (drugs)
Sample volume: ~50 µl
Throughput: ~50 samples per day (30 min LC runs)
Cost: ~1 dollar per analyte
From a drop of blood (100ul), Dr. Gerzsten is able to measure the change in over 400 metabolites.

This will allow us the opportunity to follow the changes in metabolism from correct and incorrect KAATSU and follow the changes from a series of proper KAATSU sessions.
Summary

We are utilizing scientific tools to:
1. document the physiologic changes with KAATSU Training performed correctly.
2. Distinguish between correct and incorrect KAATSU
   1. In scientific studies
   2. In teaching new instructors
3. Future studies will need to utilize these methods to prove they are doing KAATSU properly.
Summary

Dr. Sato has developed a technique (KAATSU) that will change how the world trains and rehabilitates.

And we will be able to document those beneficial effects, as well as, be able to teach the correct KAATSU training.
What is KAATSU?

Dr. Jim Stray-Gundersen, MD
Chief Medical Officer
KAATSU Global
KAATSU is:

A safe, effective, efficient method for improving specific strength in sport, leading to improved performance on the pitch.

A safe, effective, efficient method to return an injured player back to the pitch quickly.

A safe, effective, efficient method for stimulating recovery.
How does KAATSU work?

• By impeding (but not occluding) blood flow, simple easy exercises become unsustainable. This disturbance of homeostasis is transmitted to the brain, which in turn, releases an anabolic/healing neuro-humoral cascade. Since little damage was actually done, improvement in musculo-skeletal structure and function ensues rapidly.
Is KAATSU safe?

1. Approximately, 300,000 KAATSU sessions per day for years in Japan. No reports of complications.

2. National Survey
   a. 6 cases of DVT in 12,642 people undergoing ~32,000 KAATSU sessions.
      i. 1/100,000 in general population
      ii. 1/100 in hospitalized population
   b. 1 case of rhabdomyolysis in ~32,000 KAATSU sessions.
Coagulation Studies

Effects of low-intensity resistance exercise with blood flow restriction on coagulation system in healthy subjects.

Madarame H¹, Kurano M, Takano H, Iida H, Sato Y, Ohshima H, Abe T, Ishii N, Morita T, Nakajima T.

Effects of KAATSU training on haemostasis in healthy subjects


Int. J. KAATSU Training Res. 2007; 3: 11-20
Is KAATSU Efficacious?

Data denote mean increase in elbow flexor muscle strength as measured by isokinetic dynamometer.

LIO; Low-intensity with occlusion (KAATSU)
HI; High-intensity conventional training
LI; Low-intensity conventional training at the same load intensity as the LIO

* $P < 0.05$

[Takarada Y et al., 2000]

Fig. 4.3 Increase in muscle strength after KAATSU TRAINING on the elbow flexor muscle at 30 - 50% 1RM.
How does KAATSU work?

- By creating an impeded (not occluded) circulation, simple exercise becomes unsustainable.
- This produces 2 local mechanisms of vascular distension/emptying and disturbance of homeostasis in exercising muscle, both which prompt up-regulation of anabolic processes like angiogenesis and muscle hypertrophy.
- These disturbances are communicated to the CNS and the CNS responds by reflex increases in heart rate and ventilation along with initiation of an anabolic neuro-humoral cascade.
If I were to clamp the femoral vein...

Femoral venous outflow would stop.

Distal venous channels and capillary beds would dilate and distend.

The femoral artery would keep pumping blood into the extremity.

Soon (5-10 seconds), the limit of the outer fascial compartments would be reached and the limb would become congested and swollen.

Arterial inflow would slow and eventually stop.
Now, if I removed the clamp...

- The femoral vein would rapidly empty, returning blood to the heart and collapsing the venous capillary vessels.
- Arterial inflow to the extremity would resume.
- The extremity would remain maximally vasodilated.
If I were to repeatedly apply the clamp for 20 seconds and then remove it for 5 seconds, we would have created an impeded, but pulsatile, venous circulation.

• That is what we do with KAATSU Cycle, only we use a narrow band of air pressure to do so.
• And the blockage of flow is incomplete and has gradations to it.
• With KAATSU bands properly applied, we create an impeded, pulsatile venous circulation with the artery pushing blood into the extremity when it can.
You use pressures of 300-400 mmHg?!

- Imagine that the pressure of the surgical clamp is infinite. No venous blood gets by it.
- Imagine that the 300mmHg of air pressure in the band is on the outside of the extremity.
- Imagine that blood (a non-compressable liquid) forces itself past the blockage and compresses air in the band.
- Imagine that the band of pressure produced in the band reduces rapidly as it goes deeper into the extremity.
- Imagine that the band pressure starts out somewhat narrower than the cuff and that width narrows as it goes deeper into the extremity.
KAATSU at 300 mmHg
13.1 mls/min

This shows the pulse of arterial blood and
One can see some retrograde flow

Here we have the patent artery and vein above it
KAATSU pressure has little to do with the athlete’s arterial blood pressure.

- KAATSU pressure is applied to the veins and moderates venous outflow.
- Moderating venous outflow eventually modifies arterial inflow.
- Blood flow into an extremity must soon match blood flow out of the extremity. However, there is some capacitance for holding extra blood in the extremity, but once that capacitance is reached, blood flow in must match blood flow out.
Mechanism and character of blood flow in an extremity with KAATSU

- When a muscle contracts, pressures in that muscle can reach high levels.
- They squeeze any blood in the muscle or vessels in the muscle, back into the major arteries and veins.
- Veins have valves, which causes blood to flow only in one direction, back to the heart.
- With KAATSU, the veins are holding lots of blood and with muscle contraction that blood is squeezed past the pressure blockage of the band.
Mechanism and character of blood flow in an extremity with KAATSU

- Sometimes, if the pressure differentials are in favor of this, when the muscle contracts, in addition to robust venous outflow, there is retrograde arterial flow.

- With KAATSU Training, and muscle contraction happening every 1-2 seconds, an impeded, pulsatile blood flow in the extremity is established.
Mechanism and character of blood flow in an extremity with KAATSU

- With KAATSU Cycle (pressure on and off with no exercise), band inflation occurring every 20-60 seconds, followed by deflation for 5-20 seconds, similarly, an impeded, pulsatile circulation is established, including an distended vasculature distal to the band, followed by an emptying of the capillaries and veins.
KAATSU
versus tourniquets, elastic bands

• It has taken Dr. Sato, over 30 years to find just the right way to produce this impeded circulation in a safe, controlled and reliable way.

• This is why the KAATSU Master is necessary to produce and monitor this impaired circulation.

• Other methods and equipment are not capable of reproducibly creating these conditions.
KAATSU exercise leads to a “disturbance of homeostasis” in working muscle

• When light, easy exercises are added to this impeded circulation, the exercise quickly becomes unsustainable.

• $\text{pO}_2$, pH, drop to critical levels with even mild exercise (e.g. unweighted arm curls).

• High levels of lactate are generated.

• ATP levels drop, as ADP and $P_i$ levels rise.

• ATP dependant Electrolyte pumps (e.g. Ca$^{++}$) can not maintain proper electrolyte gradients.
Mechanism(s) of KAATSU

• **Local vascular mechanism:** There is alternating distension and emptying of the venous/capillary vascular space.

• **Local muscle mechanism:** There is “disturbance of homeostasis” in the muscle.

• These disturbances are communicated to the CNS.

• **Systemic mechanism:** The CNS reflex stimulates cardiovascular responses and releases an anabolic neuro-humoral cascade.
The CNS reacts

• There is a reflex initiation of a neuro-humoral-immuno anabolic/healing/adaptation cascade.

• All vascular tissues that have had this distension/emptying flow characteristics stimulate an angiogenic response.

• All muscular-tendon-bone units that have been exercising enjoy an anabolic growth response.

• Any current injuries are augmented/aided/accelerated by the healing, anabolic milieu.
Hemodynamic and hormonal responses to a short-term, low intensity, resistance exercise with the reduction of muscle blood flow

Haruhito Takano · Toshihiro Morita · Haruko Iida
Ken-ichi Asada · Masayoshi Kato · Kansei Uno
Ken Hirose · Akihiro Matsumoto · Katsu Takenaka
Yasunobu Hirata · Fumio Eto · Ryozo Nagai
Yoshiaki Sato · Toshiaki Nakajima

Conclusions

• KAATSU is safe, when proper equipment is used and Dr. Sato’s protocols are properly applied.

• KAATSU is efficacious at:
  – Building strength with short workouts (30 minutes) and in as few as 10 sessions.
  – Improving performance where specific strength is a critical parameter

• KAATSU accelerates return to sport.
Conclusions

• KAATSU simply tricks the brain into thinking a huge, horrendous workout has occurred and it must repair the damage, where in reality, little damage has been done and rebuilding just makes structure and function better rapidly.

• KAATSU allows significant maximal intensity training while injured joints, bones, and muscles heal expeditiously.
When KAATSU is used with Dr. Sato’s equipment and protocols

A safe, effective, efficient method for improving specific strength in sport, leading to improved performance on the pitch.

A safe, effective, efficient method to return an injured player back to the pitch quickly.

A safe, effective, efficient method for stimulating recovery.