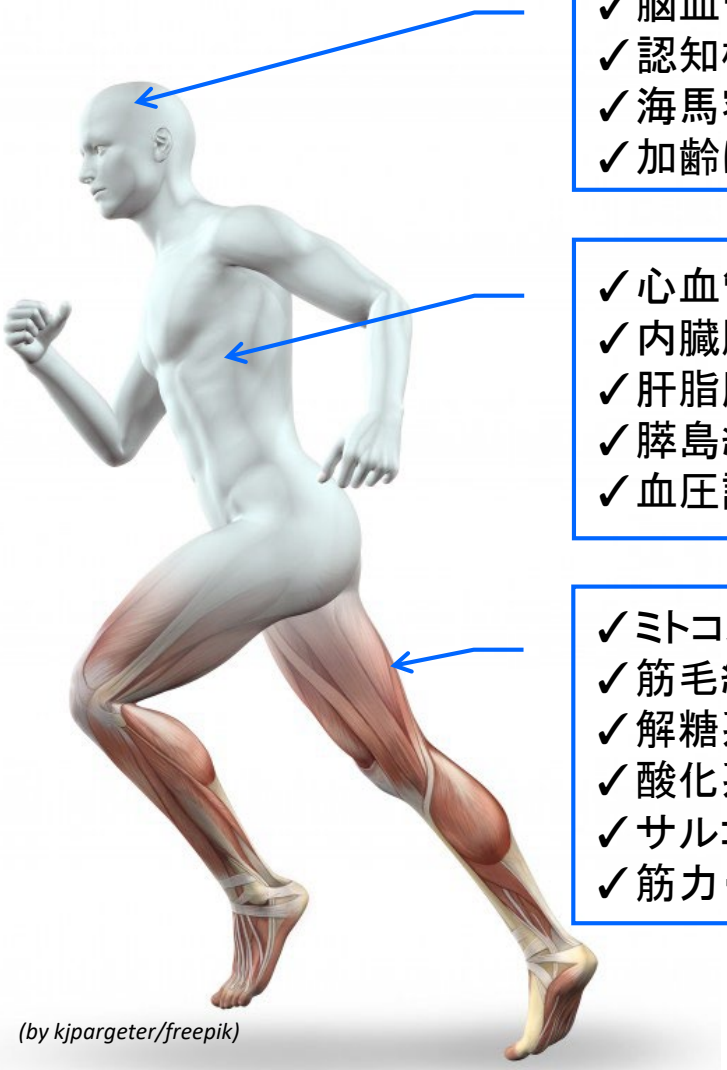
糖尿病に対する運動療法の実際
－血糖コントロールに効果的な細切れ運動－

福岡大学　スポーツ科学部　運動生理学研究室
産学官共同研究機関　身体活動研究所
檜垣　靖樹

アウトライン

- ✓ 血糖コントロールに効果的な細切れ運動とは？
- ✓ 運動指導の実際　スロージョギング編

身体活動・運動の効用



(by kjpargeter/freepik)

- ✓脳血管疾患の予防・改善
- ✓認知機能の改善
- ✓海馬容積の維持
- ✓加齢による脳萎縮抑制など

- ✓心血管疾患の予防・改善
- ✓内臓脂肪の減少
- ✓肝脂肪の減少
- ✓膵島細胞の機能維持
- ✓血圧調節の維持　など

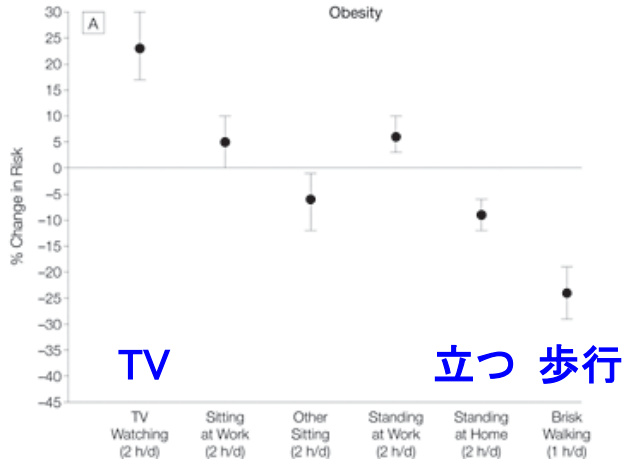
- ✓ミトコンドリア機能の向上
- ✓筋毛細血管密度の増加
- ✓解糖系酵素活性の向上
- ✓酸化系酵素活性の向上
- ✓サルコペニアの予防
- ✓筋力・柔軟性の維持　など

最大酸素摂取量の50%強度・中等度の強さ

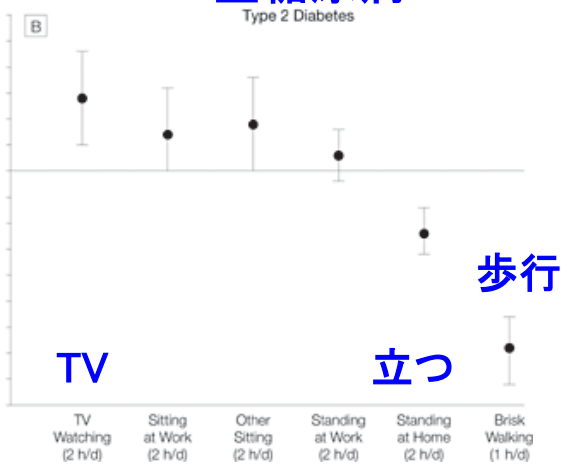
ニコニコペースの運動強度

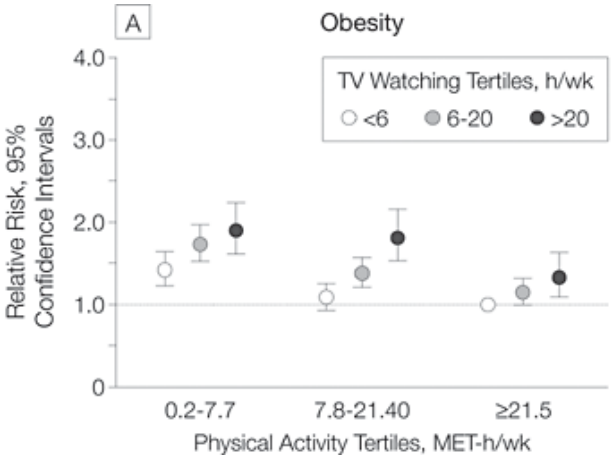
テレビの視聴時間と肥満、2型糖尿病発症リスクの関係

肥満

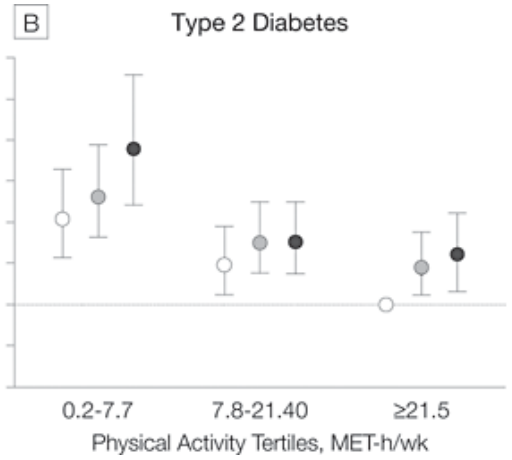


2型糖尿病





身体活動量別



身体活動量別

Nurses' Health Study
前向きコーホート研究
121,700人（30～55歳、女性）

エンドポイント：肥満、2型糖尿病

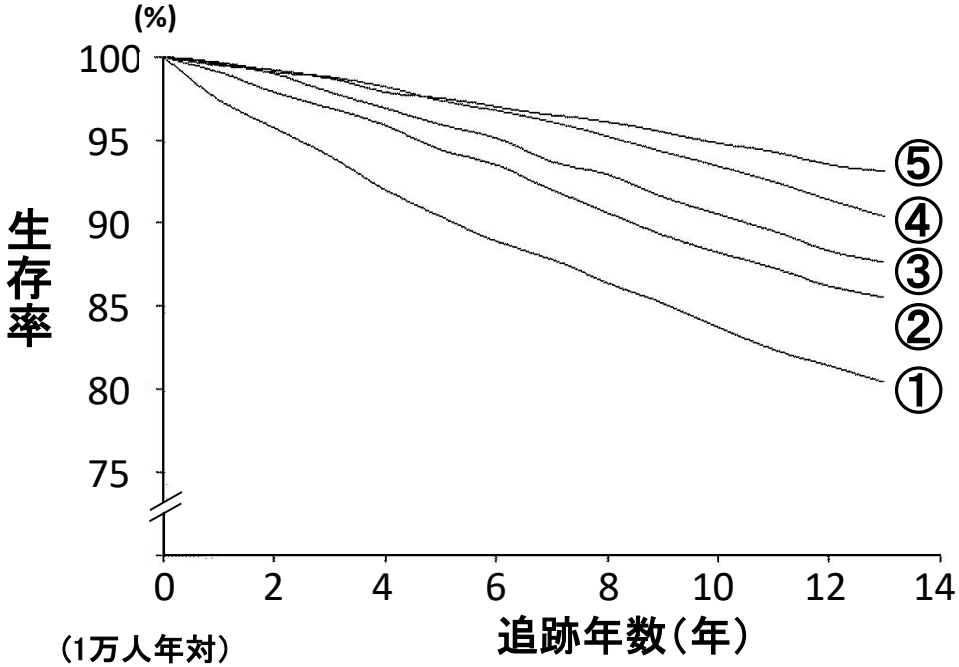
追跡期間：6年間（1992～1998）

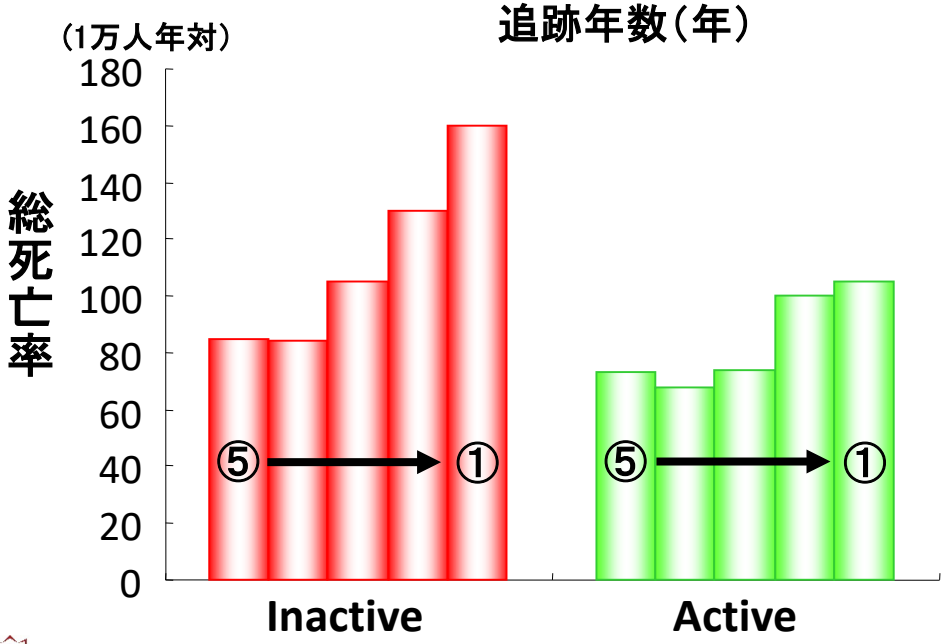
テレビ視聴・座位時間：質問紙
✔1週間当たりの時間

身体活動：質問紙
✔1週間当たりの活動内容と各実施時間

(Hu FB et al, JAMA 2003)

座位時間と総死亡率の関係





カナダフィットネス調査
17,013人(18～90歳)男女,1981年

エンドポイント:死亡(データベース)
1981年～1993年追跡

身体活動調査:質問紙
3メッツ以上の余暇活動19項目
3メッツ未満の余暇活動1項目

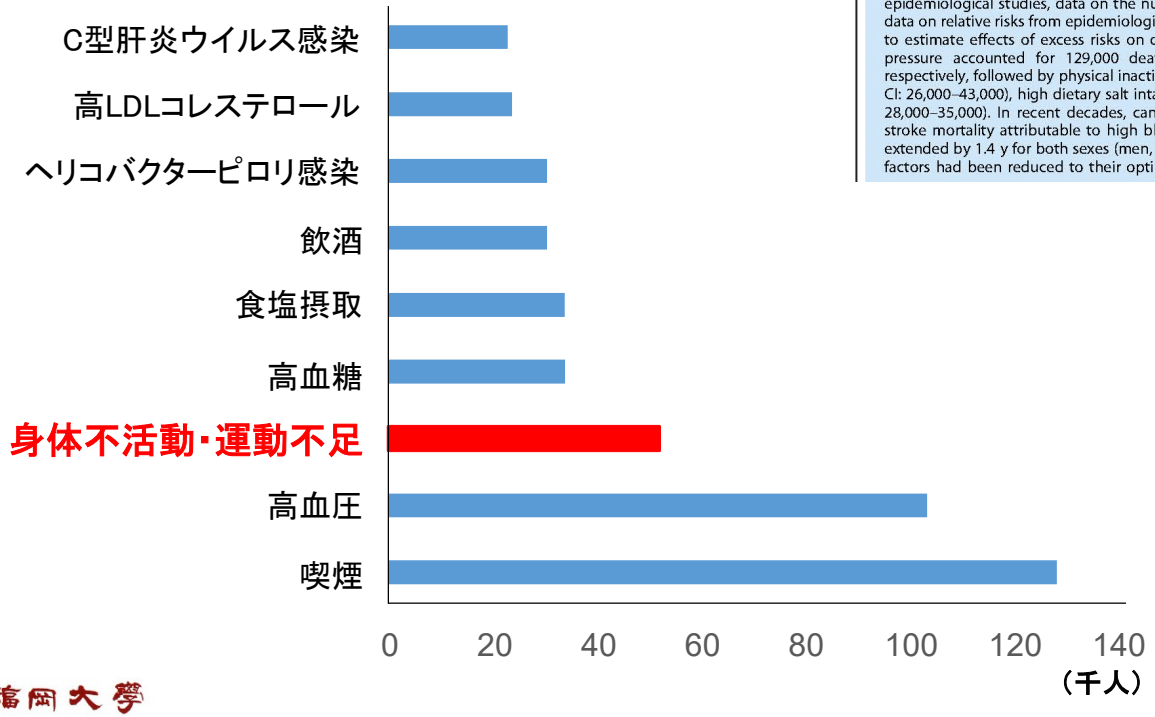
座位時間:質問紙
①ほとんど座っている
②75%は座っている
③50%は座っている
④25%は座っている
⑤ほとんど座っている時間はない

7.5 MET・h/wk以上を"Active"
7.5 MET・h/wk未満を"Inactive"

(katzmarzyk et al, Med Sci Sports Exerc 2009)

身体不活動・運動不足は
リスク別要因の第3位

我が国におけるリスク要因別の
関連死亡者数(2007年)



OPEN ACCESS Freely available online PLoS MEDICINE

Adult Mortality Attributable to Preventable Risk Factors for Non-Communicable Diseases and Injuries in Japan: A Comparative Risk Assessment

Nayu Ikeda[1]*, Manami Inoue[2], Hiroyasu Iso[3], Shunya Ikeda[4], Toshihiko Satoh[5], Mitsuhiko Noda[6], Tetsuya Mizoue[7], Hironori Imano[3], Eiko Saito[1], Kota Katanoda[8], Tomotaka Sobue[8], Shoichiro Tsugane[2], Mohsen Naghavi[9], Majid Ezzati[10], Kenji Shibuya[1]

1 Department of Global Health Policy, Graduate School of Medicine, University of Tokyo, Tokyo, Japan, 2 Epidemiology and Prevention Division, Research Center for Cancer Prevention and Screening, National Cancer Center, Tokyo, Japan, 3 Department of Social and Environmental Medicine, Osaka University Graduate School of Medicine, Osaka, Japan, 4 International University of Health and Welfare Graduate School, Tokyo, Japan, 5 Kitasato Clinical Research Center, Kitasato University School of Medicine, Sagamihara, Japan, 6 Department of Diabetes and Metabolic Medicine, National Center for Global Health and Medicine, Tokyo, Japan, 7 Department of Epidemiology and International Health, National Center for Global Health and Medicine, Tokyo, Japan, 8 Cancer Information Services and Surveillance Division, Center for Cancer Control and Information Services, National Cancer Center, Tokyo, Japan, 9 Institute for Health Metrics and Evaluation, University of Washington, Seattle, Washington, United States of America, 10 MRC-HPA Centre for Environment and Health, Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, United Kingdom

Abstract

Background: The population of Japan has achieved the longest life expectancy in the world. To further improve population health, consistent and comparative evidence on mortality attributable to preventable risk factors is necessary for setting priorities for health policies and programs. Although several past studies have quantified the impact of individual risk factors in Japan, to our knowledge no study has assessed and compared the effects of multiple modifiable risk factors for non-communicable diseases and injuries using a standard framework. We estimated the effects of 16 risk factors on cause-specific deaths and life expectancy in Japan.

Methods and Findings: We obtained data on risk factor exposures from the National Health and Nutrition Survey and epidemiological studies, data on the number of cause-specific deaths from vital records adjusted for ill-defined codes, and data on relative risks from epidemiological studies and meta-analyses. We applied a comparative risk assessment framework to estimate effects of excess risks on deaths and life expectancy at age 40 y. In 2007, tobacco smoking and high blood pressure accounted for 129,000 deaths (95% CI: 115,000–154,000) and 104,000 deaths (95% CI: 86,000–119,000), respectively, followed by physical inactivity (52,000 deaths, 95% CI: 47,000–58,000), high blood glucose (34,000 deaths, 95% CI: 26,000–43,000), high dietary salt intake (34,000 deaths, 95% CI: 27,000–39,000), and alcohol use (31,000 deaths, 95% CI: 28,000–35,000). In recent decades, cancer mortality attributable to tobacco smoking has increased in the elderly, while stroke mortality attributable to high blood pressure has declined. Life expectancy at age 40 y in 2007 would have been extended by 1.4 y for both sexes (men, 95% CI: 1.3–1.6; women, 95% CI: 1.2–1.7) if exposures to multiple cardiovascular risk factors had been reduced to their optimal levels as determined by a theoretical-minimum-risk exposure distribution.

(PLoS Med., 2012)

2週間の活動制限がスタミナ度，パワー，下肢筋量，インスリン感受性に及ぼす影響

J Appl Physiol 108: 1034–1040, 2010.
First published December 31, 2009; doi:10.1152/japplphysiol.00977.2009. ***(J Appl Physiol, 2009)***

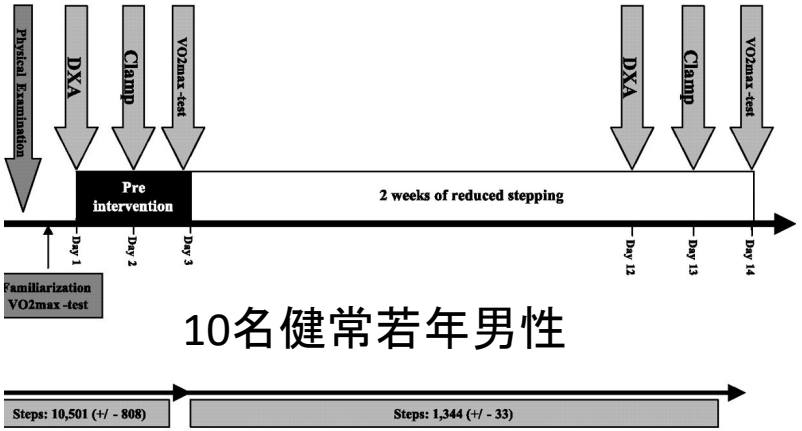
A 2-wk reduction of ambulatory activity attenuates peripheral insulin sensitivity

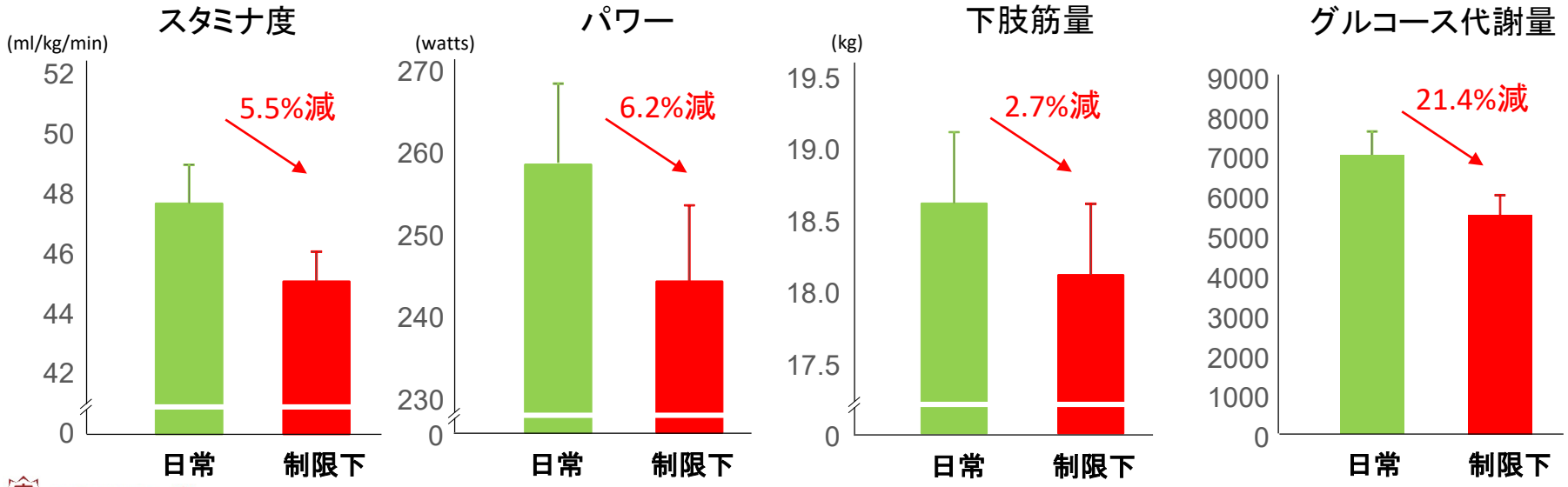
Rikke Krogh-Madsen,[1] John P. Thyfault,[2] Christa Broholm,[1] Ole Hartvig Mortensen,[1] Rasmus H. Olsen,[1] Remi Mounier,[1] Peter Plomgaard,[1] Gerrit van Hall,[1] Frank W. Booth,[3] and Bente K. Pedersen[1]

[1]Centre of Inflammation and Metabolism at Department of Infectious Diseases and Copenhagen Muscle Research Centre, Rigshospitalet, Faculty of Health Sciences, University of Copenhagen, Copenhagen, Denmark; [2]Harry S. Truman Memorial Veterans Hospital, Health Activity Center, Departments of Nutrition and Exercise Physiology and Internal Medicine, University of Missouri, Columbia, Missouri; and [3]Health Activity Center, Departments of Biomedical Sciences and of Medical Pharmacology and Physiology, University of Missouri, Columbia, Missouri

Submitted 30 August 2009; accepted in final form 29 December 2009

Krogh-Madsen R, Thyfault JP, Broholm C, Mortensen OH, Olsen RH, Mounier R, Plomgaard P, van Hall G, Booth FW, Pedersen BK. A 2-wk reduction of ambulatory activity attenuates peripheral insulin sensitivity. *J Appl Physiol* 108: 1034–1040, 2010. First published December 31, 2009; doi:10.1152/japplphysiol.00977.2009.—US adults take between ~2,000 and ~12,000 steps per day, a wide range of ambulatory activity that at the low range could increase risk for developing chronic metabolic diseases. Dramatic reductions in physical and at the low range may increase risk for developing chronic metabolic disease(s) (4). We postulated that healthy, nonexercising subjects who transitioned from a high to low level of ambulatory activity (from >10,000 to <2,000) would quickly display metabolic alterations. Our initial findings showed that healthy young men who reduced their daily steps from an average of 10,501 ± 808 to 1,344 ± 33 for a 2-wk period displayed a clustering of metabolic alterations including in-





スタンドブレイクによる急性効果

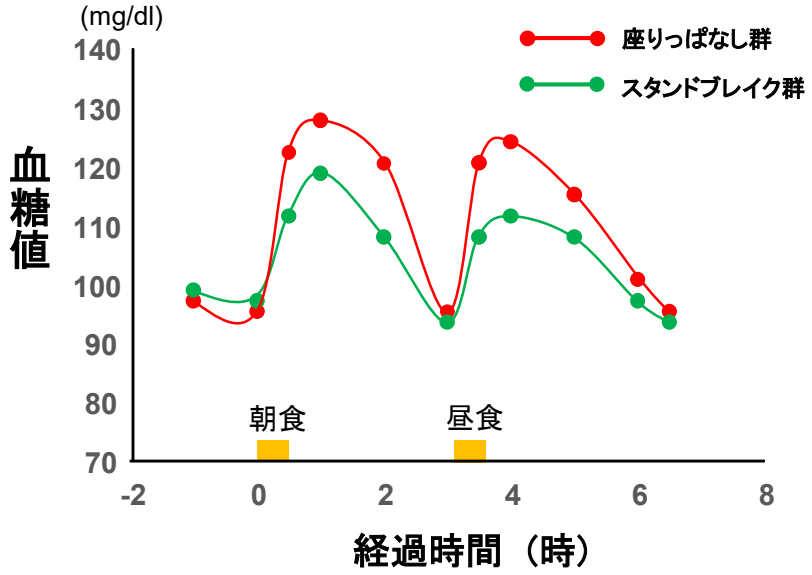
高齢女性の肥満者22名
年齢：66.6 ±4.7 yr
BMI：32.9±4.7　kg/m^2
HbA1c：5.8±0.2　%

30 Diabetes Care Volume 39, January 2016

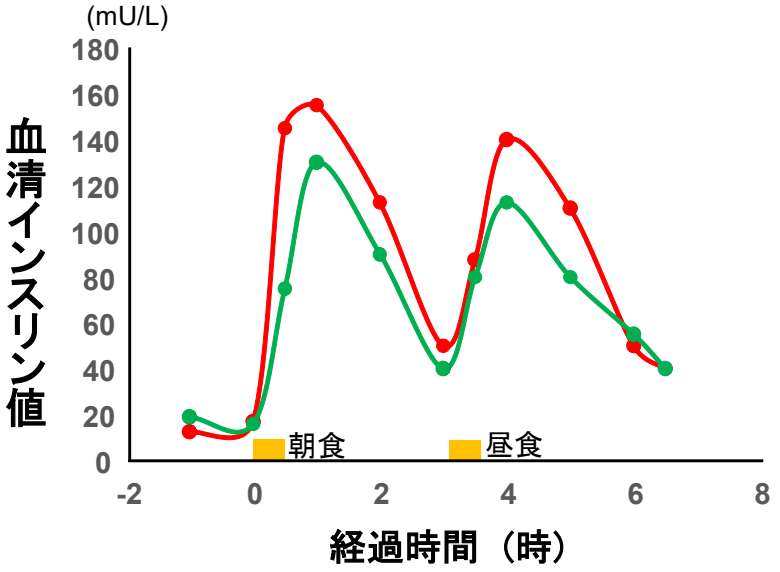
Breaking Up Prolonged Sitting With Standing or Walking Attenuates the Postprandial Metabolic Response in Postmenopausal Women: A Randomized Acute Study

Joseph Henson,[1,2] Melanie J. Davies,[1,2] Danielle H. Bodicoat,[1,2,3] Charlotte L. Edwardson,[1,2] Jason M.R. Gill,[4] David J. Stensel,[2,5] Keith Tolfrey,[2,5] David W. Dunstan,[6,7] Kamlesh Khunti,[2,3] and Thomas Yates[1,2]

Diabetes Care 2016;39:130–138 | DOI: 10.2337/dc15-1240



左図　座りっぱなし群とスタンドブレイク群の血糖値の変動



右図　座りっぱなし群とスタンドブレイク群の血清インスリン値の変動

座りっぱなし群：ずっと座ったまま仕事をする
スタンドブレイク群：30分毎に5分間だけ立って仕事をする

(Yates T et al, Diabetes Care, 2016)

細切れ運動による朝食および昼食後の血糖変動

964 Diabetes Care Volume 39, June 2016

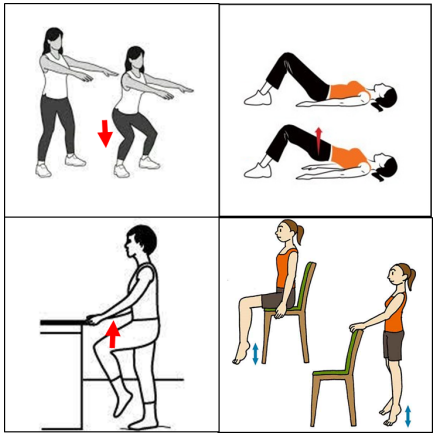
Benefits for Type 2 Diabetes of Interrupting Prolonged Sitting With Brief Bouts of Light Walking or Simple Resistance Activities

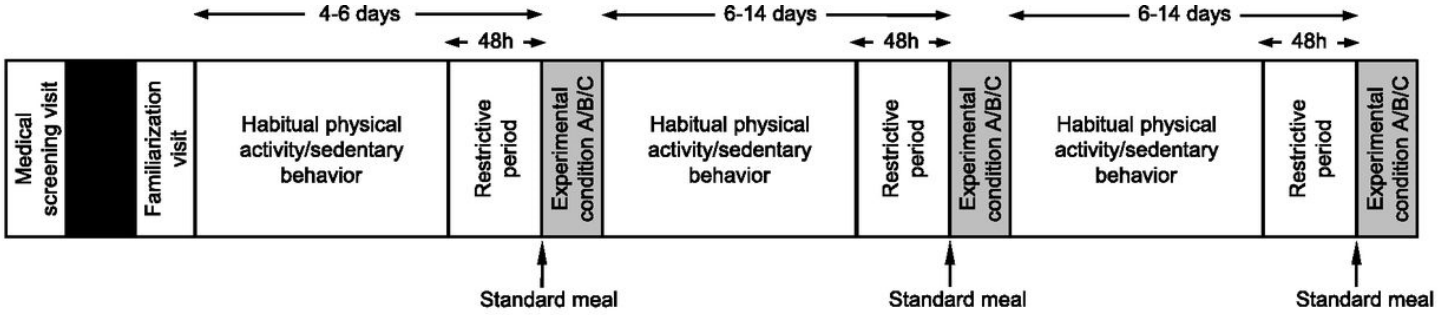
Paddy C. Dempsey,[1,2] Robyn N. Larsen,[1] Parneet Sethi,[1] Julian W. Sacre,[1] Nora E. Straznicky,[1] Neale D. Cohen,[1] Ester Cerin,[1,3,4] Gavin W. Lambert,[1,2] Neville Owen,[1] Bronwyn A. Kingwell,[1] and David W. Dunstan[1,3,5]

Diabetes Care 2016;39:964–972 | DOI: 10.2337/dc15-2336

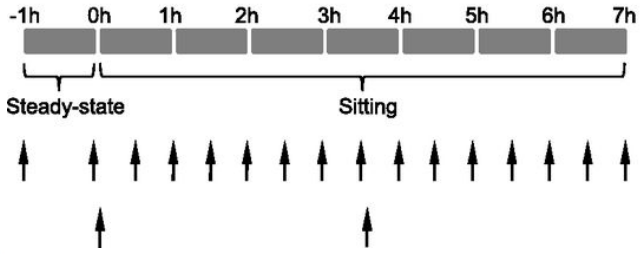
3 min walking

3 min resistance activities

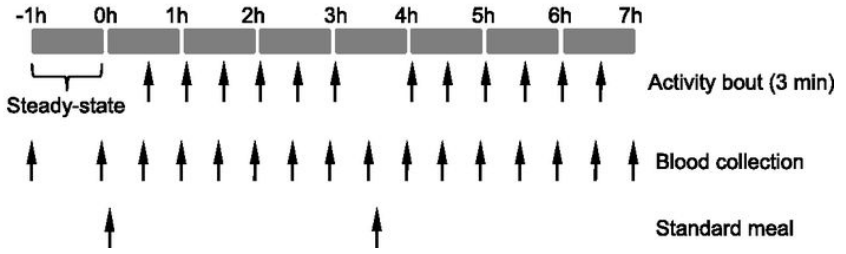




SIT: UNINTERRUPTED SITTING



LW: SITTING + 3 MIN BOUTS OF LIGHT-INTENSITY **W**ALKING
SRA: SITTING + 3 MIN BOUTS OF **S**IMPLE **R**ESISTANCE **A**CTIVITIES



細切れ運動による朝食および昼食後の血糖変動

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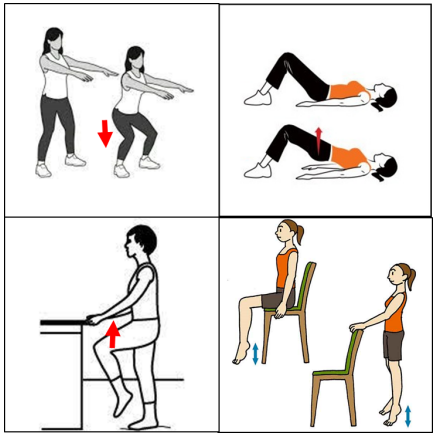
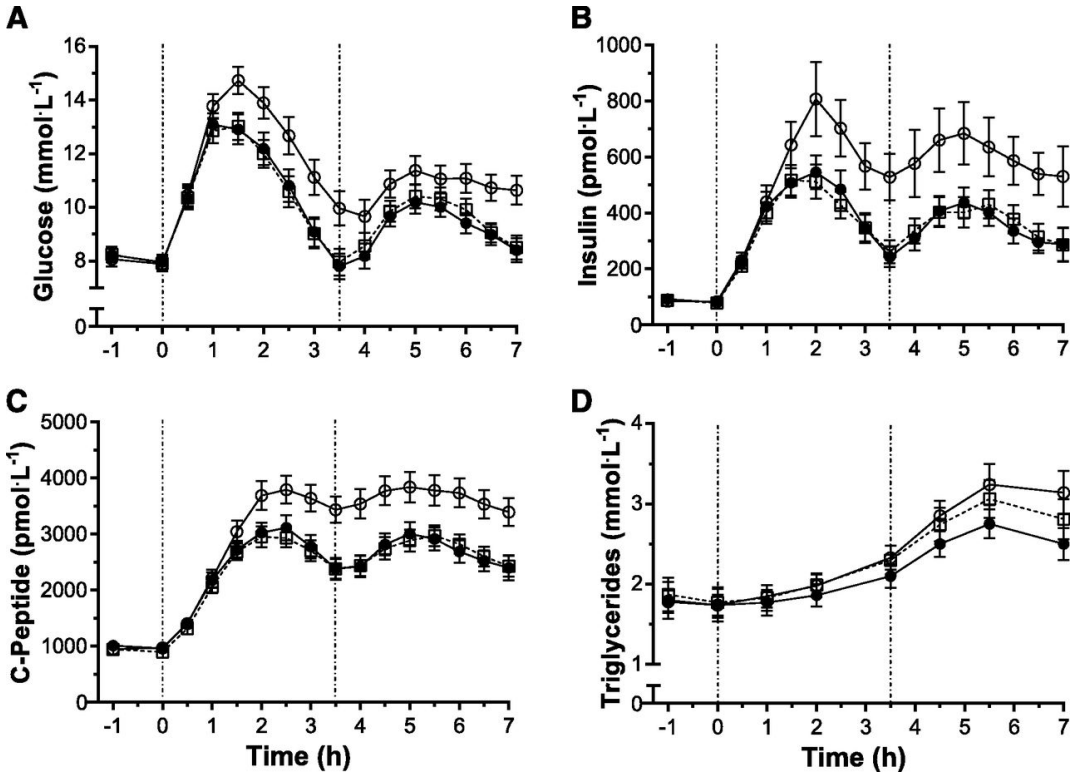
3 min resistance activities





○ 座位安静

□ 3 min walking

■ 3 min resistance activities

運動のタイミングと24時間血糖値変動

J Appl Physiol 123: 278–284, 2017.
First published April 13, 2017; doi:10.1152/japplphysiol.00608.2016.

RESEARCH ARTICLE

Effect of exercise timing on elevated postprandial glucose levels

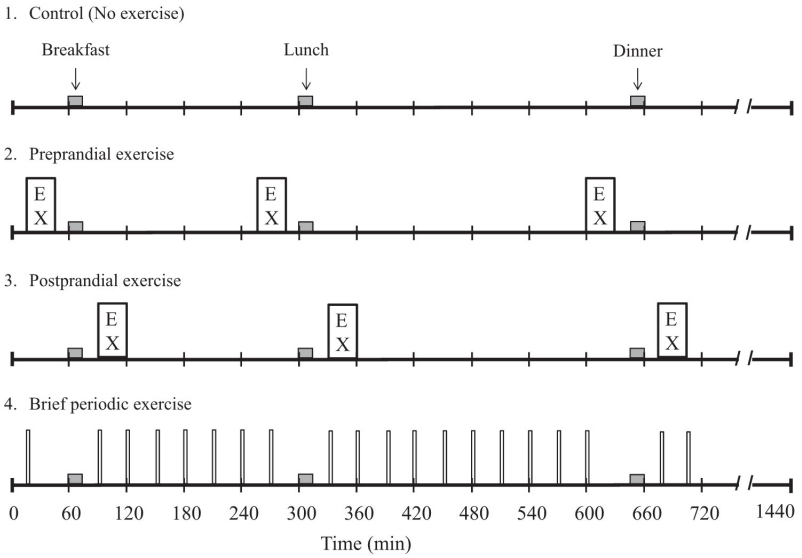
Yoichi Hatamoto,[1] Ryoma Goya,[2] Yosuke Yamada,[1,3] Eichi Yoshimura,[4] Sena Nishimura,[2] Yasuki Higaki,[1,2] and Hiroaki Tanaka[1,2]

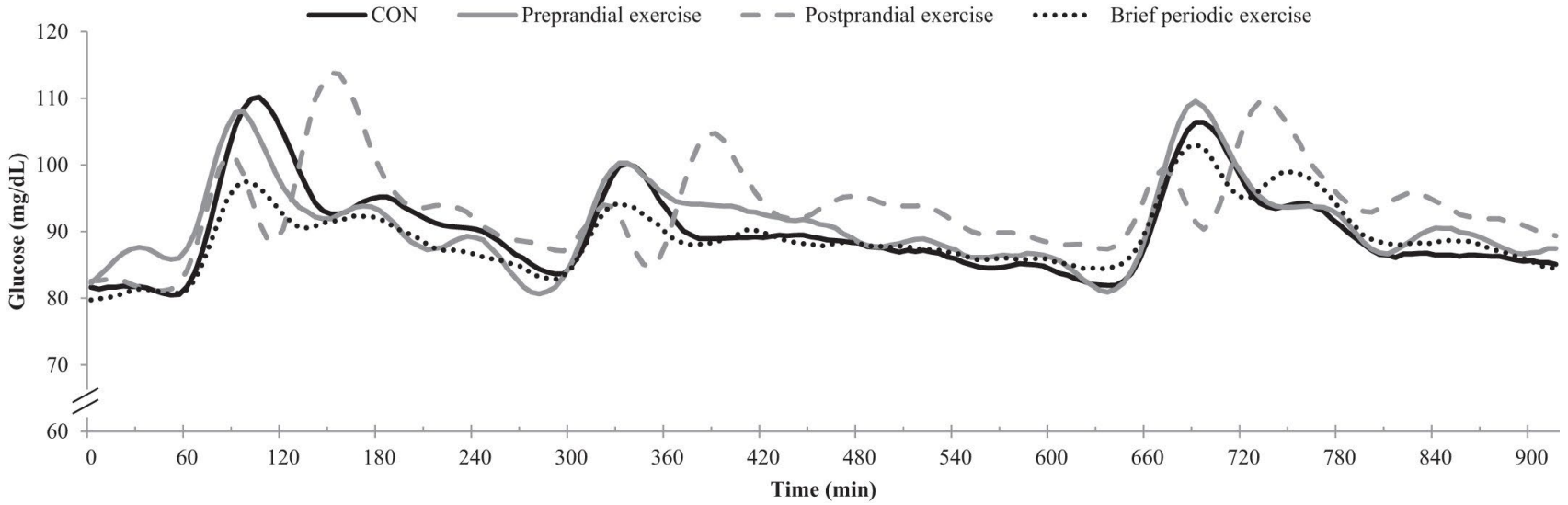
[1]*The Fukuoka University Institute for Physical Activity, Fukuoka, Japan;* [2]*Graduate School of Sports and Health Science, Fukuoka University, Fukuoka, Japan;* [3]*Department of Nutritional Science, National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, Tokyo, Japan; and* [4]*Department of Food and Health Sciences, Prefectural University of Kumamoto Faculty of Environmental and Symbiotic Sciences, Kumamoto, Japan*

Submitted 6 July 2016; accepted in final form 11 April 2017

Hatamoto Y, Goya R, Yamada Y, Yoshimura E, Nishimura S, Higaki Y, Tanaka H. Effect of exercise timing on elevated postprandial glucose levels. *J Appl Physiol* 123: 278–284, 2017. First published April 13, 2017; doi:10.1152/japplphysiol.00608.2016.—There is no consensus regarding optimal exercise timing for reducing postprandial glucose (PPG). The purpose of the present study was to determine the most effective exercise timing. Eleven participants completed four different exercise patterns *1*) no exercise; *2*) prepran-

Type 2 diabetes. In addition, in nondiabetic populations, elevated PPG is a risk factor for coronary heart disease, ischemic stroke (24), and CVD (21). Endothelial dysfunction, which is predictive of a future cardiovascular event, is caused by hyperglycemia through oxidative stress (4). Furthermore, oscillating glucose levels increase oxidative stress more than constant high glucose levels and have a more deleterious effect on





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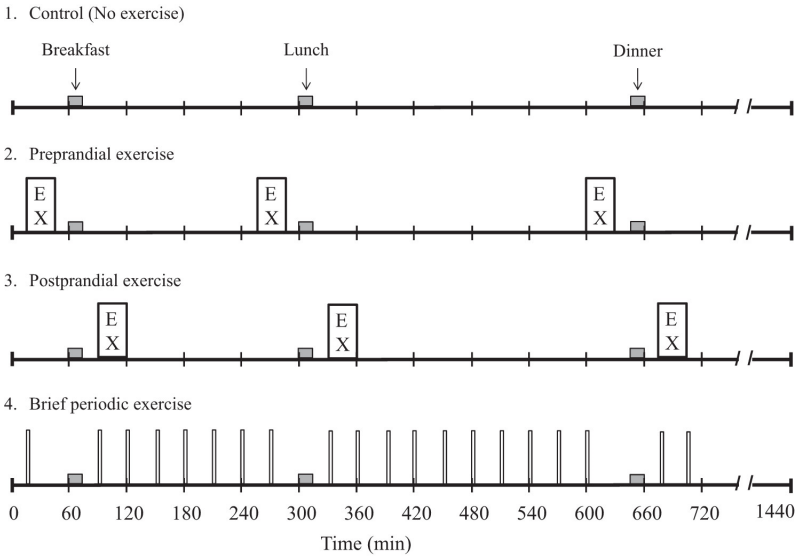
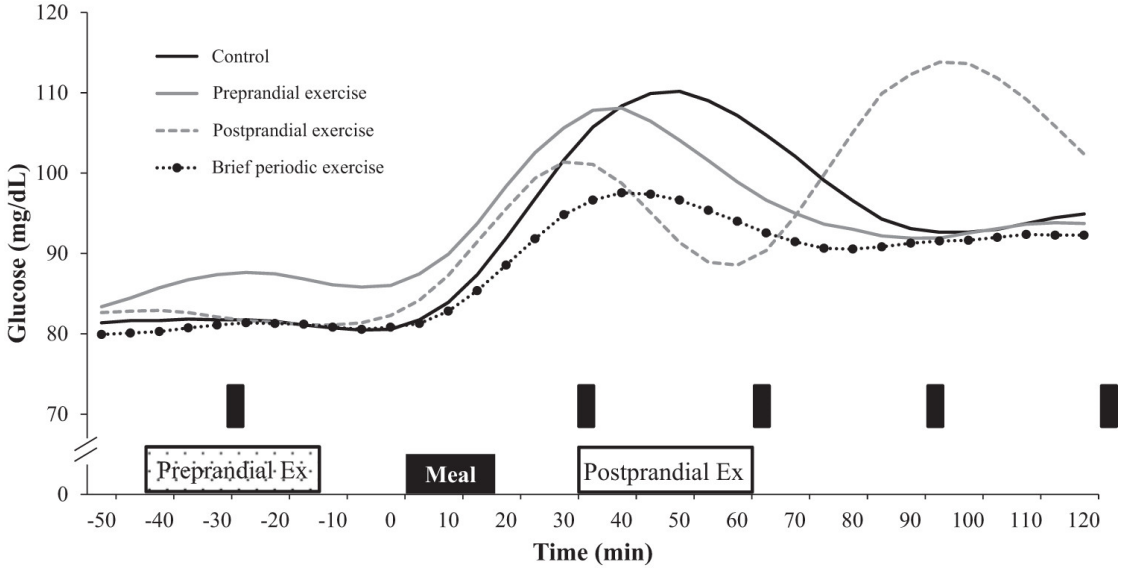




細切れ運動の持続時間及び細切れ運動の間隔の違いが血糖値に及ぼす影響

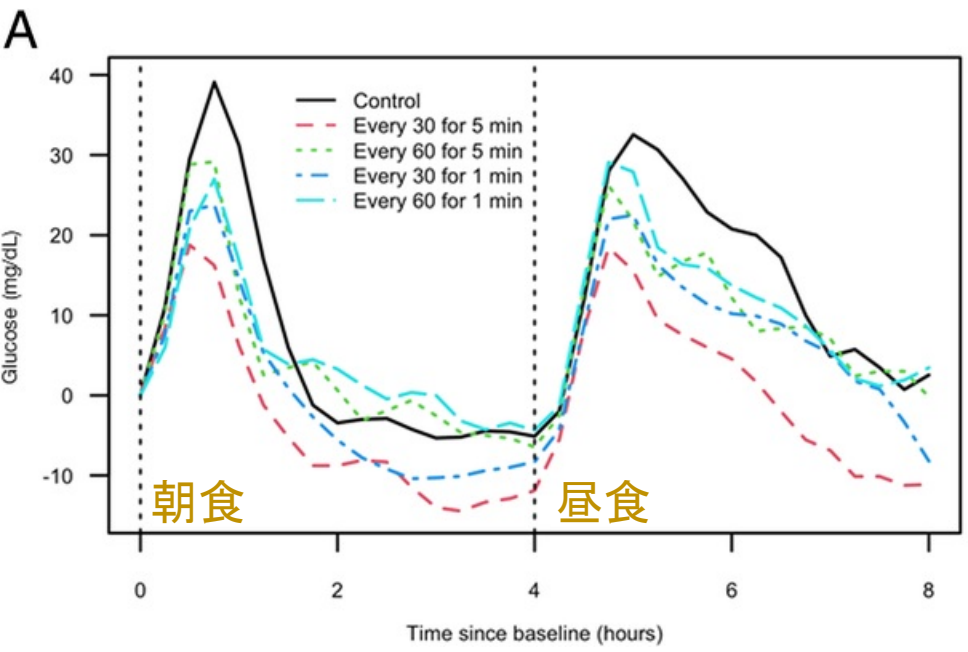
Breaking Up Prolonged Sitting to Improve Cardiometabolic Risk: Dose–Response Analysis of a Randomized Crossover Trial

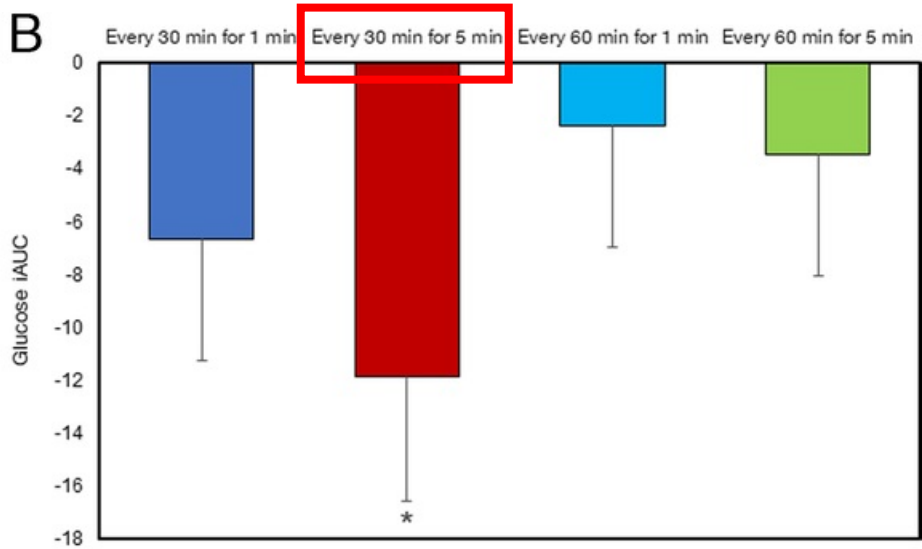
ANDREA T. DURAN[1], CIARAN P. FRIEL[2], MARIA A. SERAFINI[1], IPEK ENSARI[3], YING KUEN CHEUNG[4], and KEITH M. DIAZ[1]

[1]Center for Behavioral Cardiovascular Health, Department of Medicine, Columbia University Medical Center, New York, NY; [2]Institute of Health System Science, Feinstein Institutes of Medical Research, Northwell Health, Manhasset, NY; [3]Hasso Plattner Institute for Digital Health at Mount Sinai, Icahn School of Medicine at Mount Sinai, New York, NY; and [4]Department of Biostatistics, Mailman School of Public Health, Columbia University, New York, NY

45歳以上の11名（平均年齢57歳，男6名・女5名），BMI；28.3kg/m^2（肥満者を含む），
空腹時血糖値；85.5±10.2mg/dl（糖尿病者を含まない）

運動；ウォーキング(light-intensity walking, HRの平均値が87～96拍/分程度）
■30分に1分間，■30分に5分間，■60分に1分間，■60分に5分間，■座位安静





(Duran AT et al, Med Sci Sports Exerc 2023)

1回のトレーニング持続時間の違いが血糖値に及ぼす影響

対象者：Ⅱ型糖尿病患者18名
方　法：最大酸素摂取量の60%強度
　　6回/週、5週間

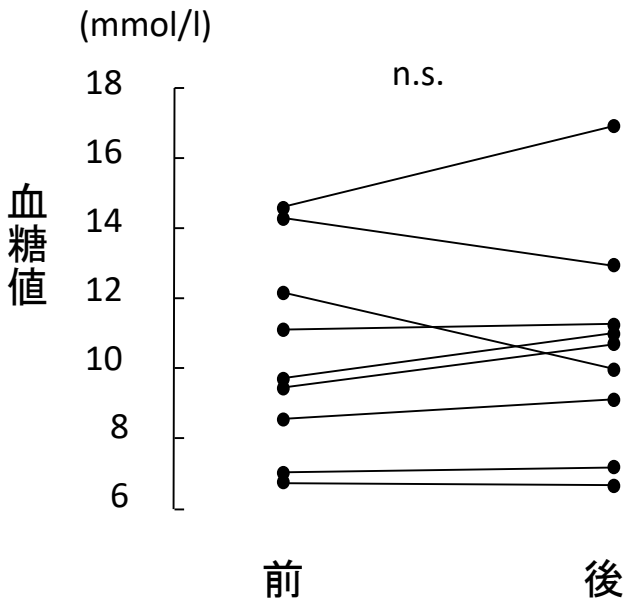
Diabetologia (2007) 50:2245–2253
DOI 10.1007/s00125-007-0783-0

ARTICLE

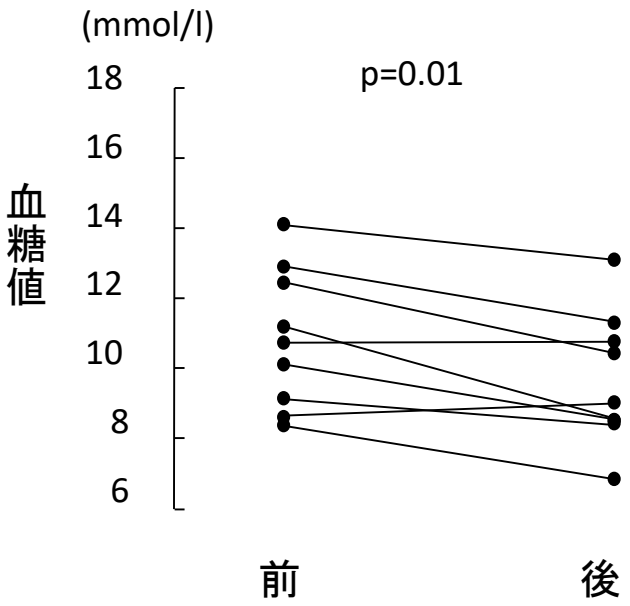
Comparison of the effect of multiple short-duration with single long-duration exercise sessions on glucose homeostasis in type 2 diabetes mellitus

L. Eriksen · I. Dahl-Petersen · S. B. Haugaard · F. Dela

1回×30分のトレーニング



3回×10分のトレーニング



(Eriksen et al, Diabetlogia, 2007)

身体活動のタイミングと総死亡の関係

nature communications

Article

https://doi.org/10.1038/s41467-023-36546-5

Associations of timing of physical activity with all-cause and cause-specific mortality in a prospective cohort study

Received: 6 September 2022

Accepted: 6 February 2023

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Check for updates

Hongliang Feng[1,2,12], Lulu Yang[1,12], Yannis Yan Liang[1,12] ✉, Sizhi Ai[3,4,5], Yaping Liu[2,5], Yue Liu[1], Xinyi Jin[1], Binbin Lei[1], Jing Wang[3,5], Nana Zheng[3], Xinru Chen[1,3], Joey W. Y. Chan[2,5], Raymond Kim Wai Sum[6], Ngan Yin Chan[2,5], Xiao Tan[7,8], Christian Benedict[9], Yun Kwok Wing[2,5] & Jihui Zhang[3,5,10,11] ✉

対象者：92,139人のUK Biobank登録者

追跡期間：7年間

評価項目：加速度計による身体活動量

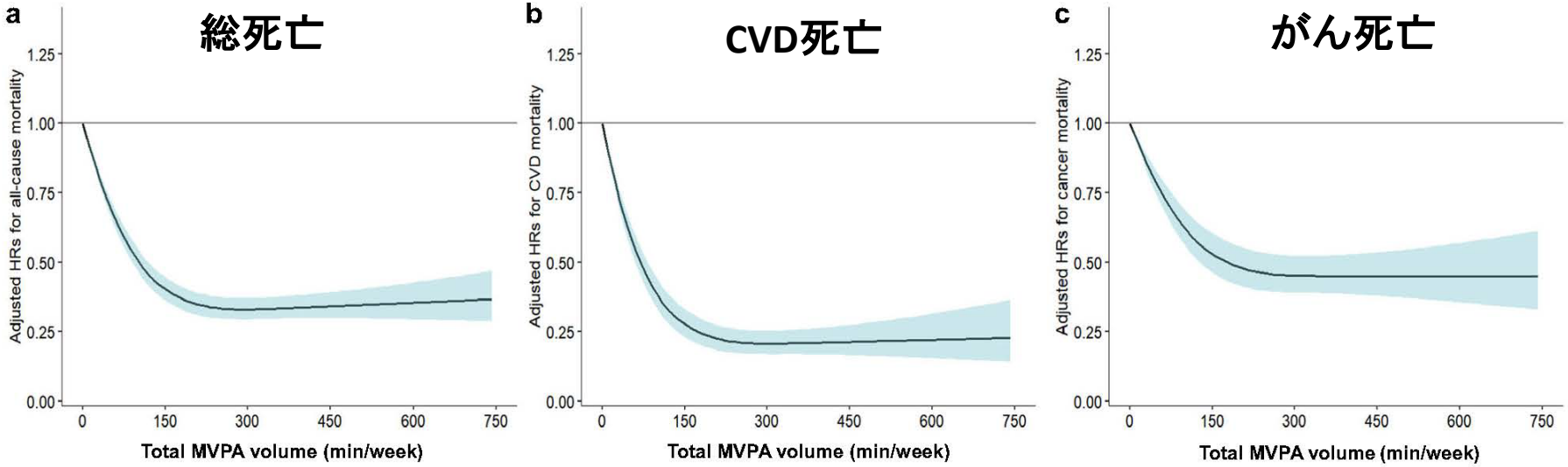
総死亡・CVD及びがん死亡

タイミング：　05:00–11:00

11:00–17:00

17:00–24:00

MVPA; Moderate-to-vigorous intensity physical activity 活発な強度の身体活動



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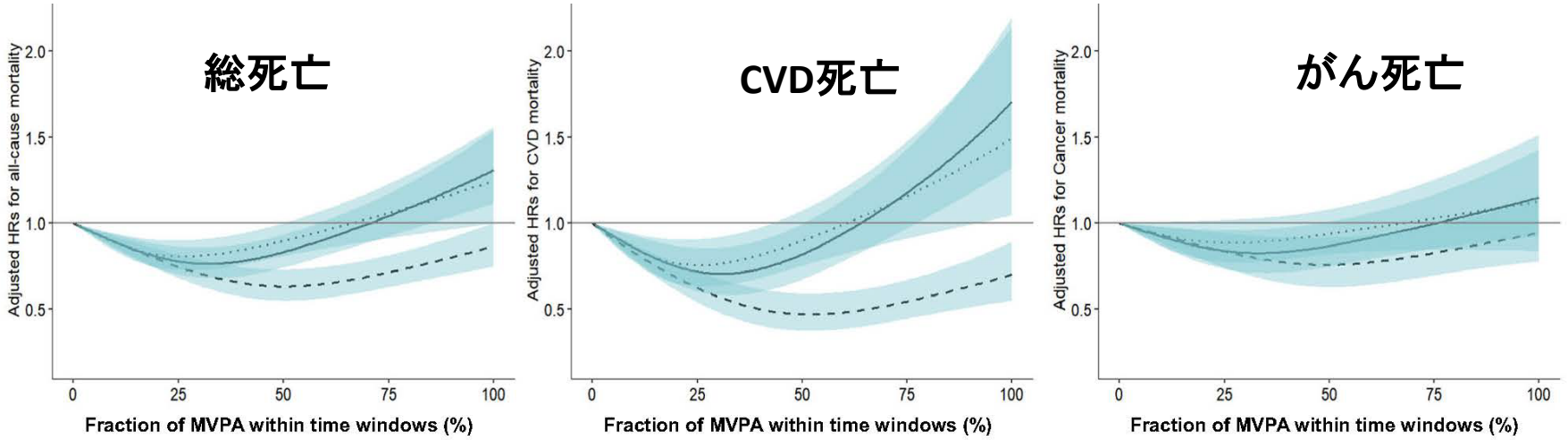
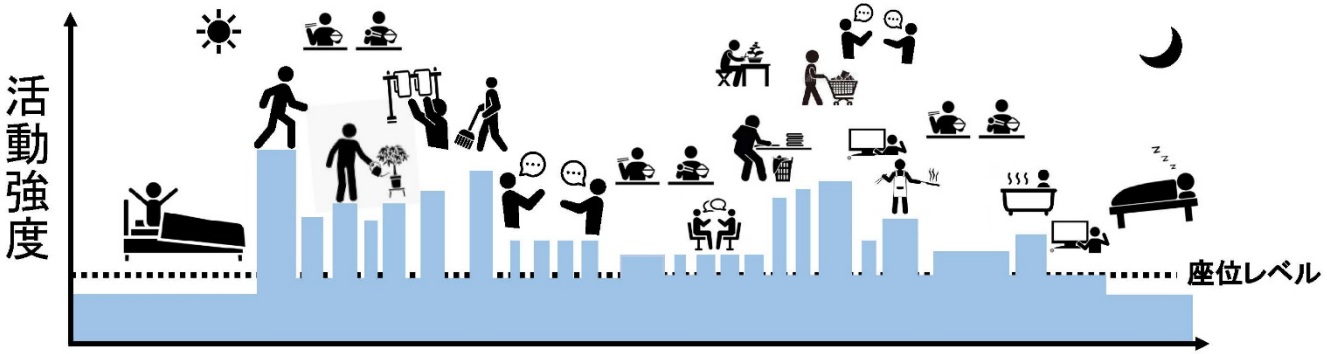


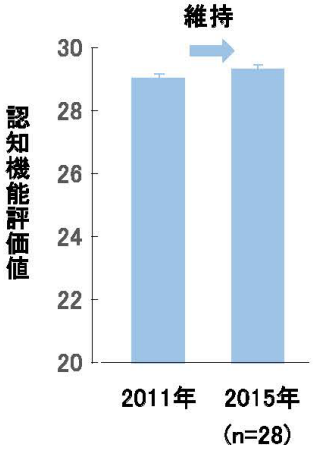
日常生活のメリハリの少なさは認知機能低下に関連する

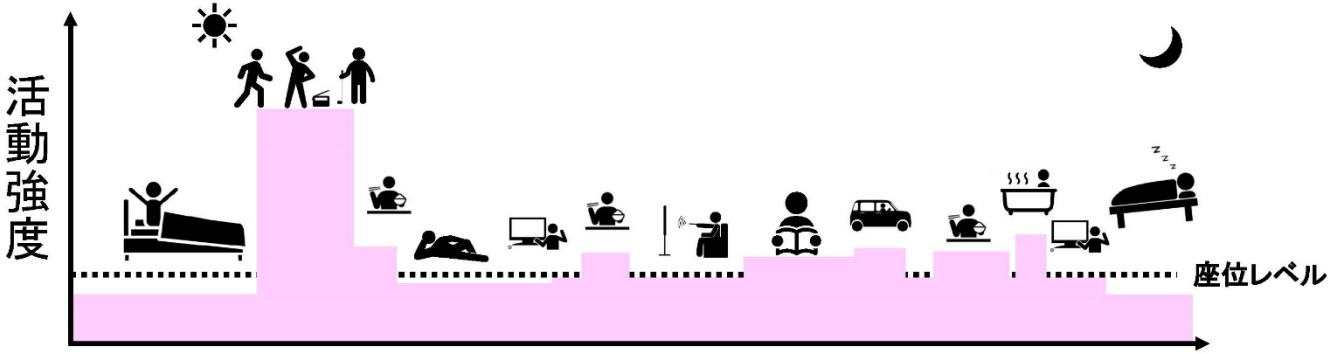
対象者：65歳以上の高齢者1073名を対象としたベースライン調査（2011年）のうち認知機能低下疑いを除外した1000名。2015年に二次調査を実施し、データ欠損のない389名を分析対象。（那珂川研究，田中宏暁代表）

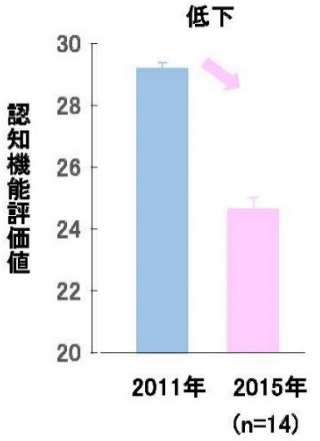
追跡期間：4年間（現在も進行中）

評価項目：MMSE, CDR, 3軸加速度歩数計，生活習慣調査票など









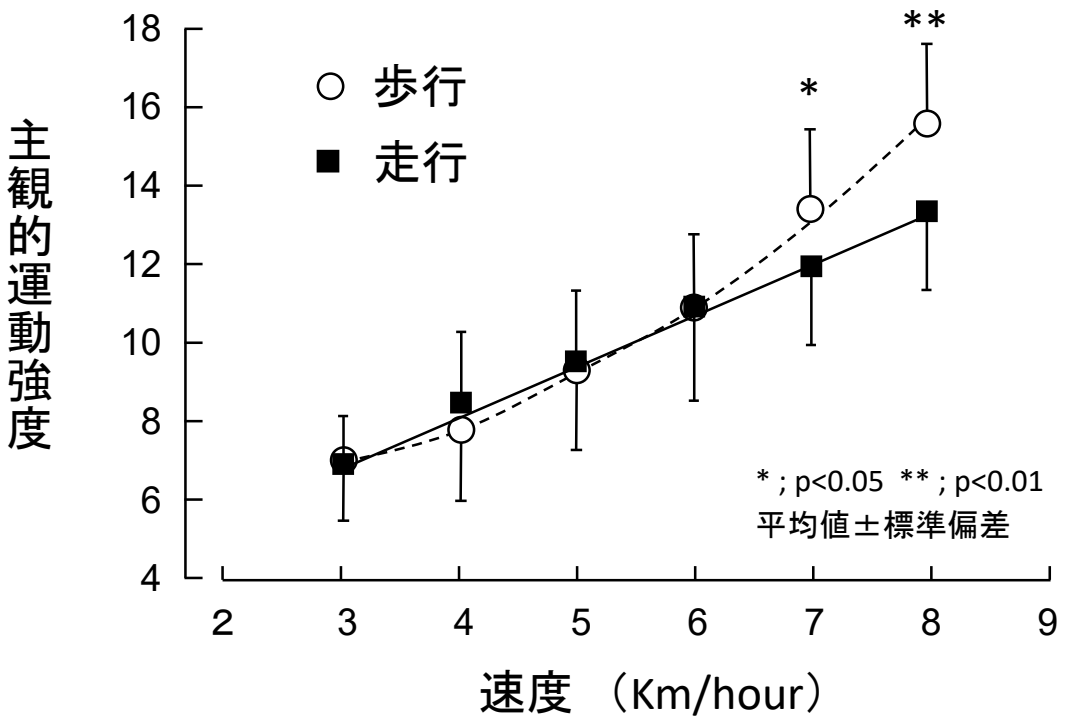
（西山・檜垣ら，ニューマンインターフェース学会誌，2020より改変）

アウトライン

✓ 血糖コントロールに有効な運動とは？

✓ **運動指導の実際　スロージョギング編**

速度と主観的運動強度の関係



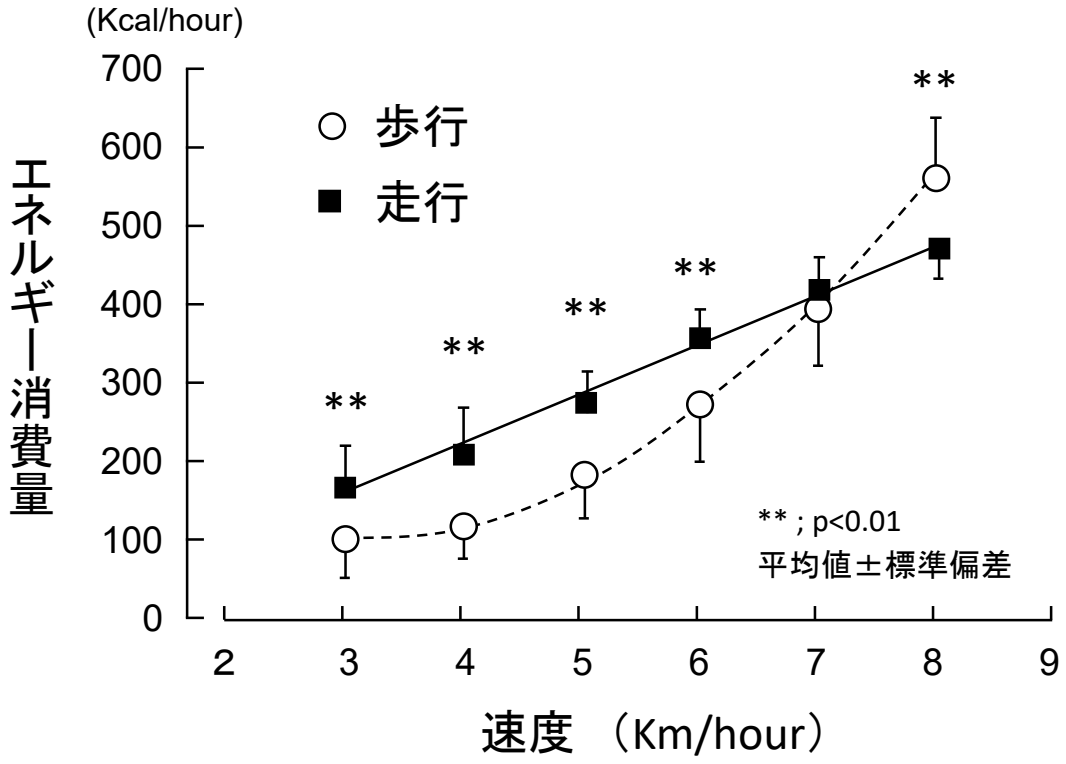
主観的運動強度
（ボルグのスケール）

20	
19	非常にきつい
18	
17	かなりきつい
16	
15	きつい
14	
13	ややきつい
12	
11	楽である
10	
9	かなり楽である
8	
7	非常に楽である
6	

低速時の主観的運動強度は歩行も走行も同じ

（北嶋康雄ら：ランニング学研究 25：19-27.2014）

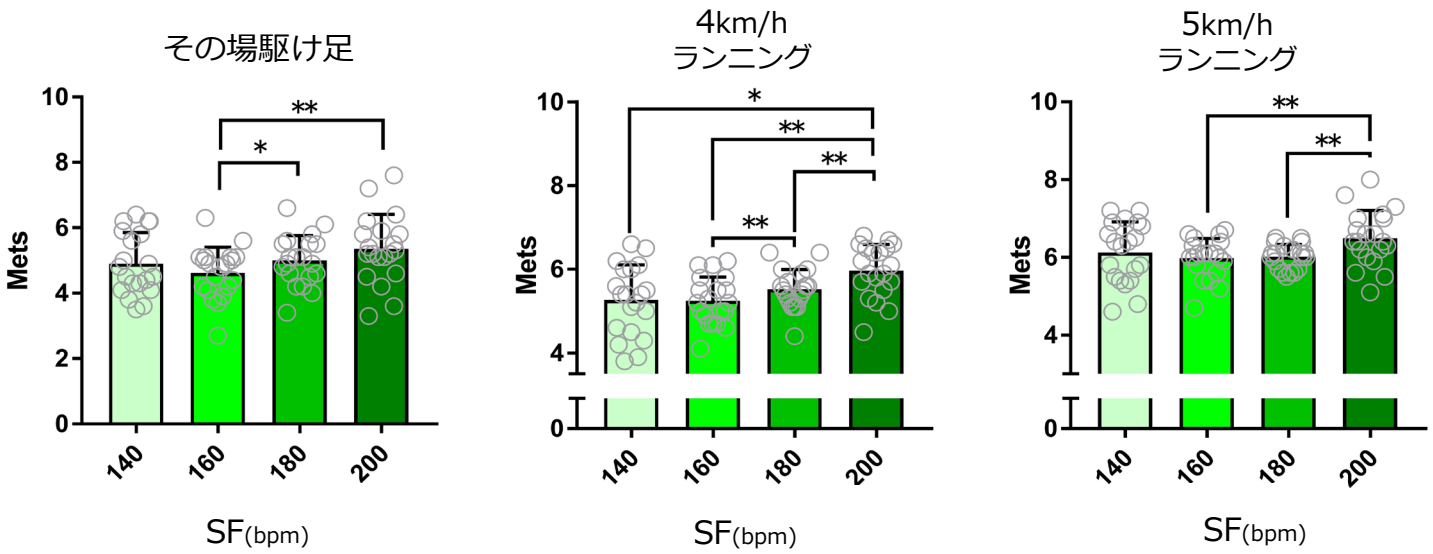
速度とエネルギー消費量の関係



低速時のエネルギー消費量は歩行に比べ、走行で1.6～2.0倍

（北嶋康雄ら：ランニング学研究 25：19-27.2014）

低速度ランニングにおける
異なるステップ頻度と酸素消費量の関係



エネルギー消費量は、ピッチに依存して増加する

(Sato N et al, JPFSM in print)

12週間のスロージョギングトレーニングによる効果

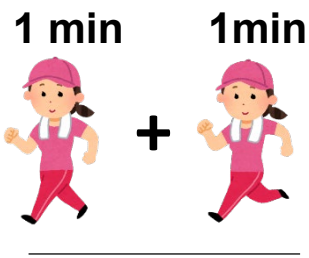
Eur J Appl Physiol
DOI 10.1007/s00421-016-3493-9

ORIGINAL ARTICLE

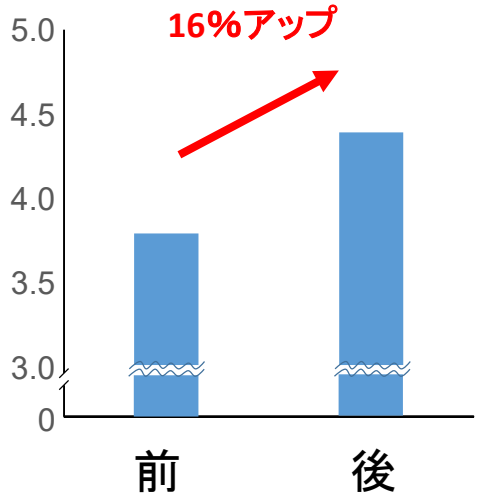
Effects of a 12-week, short-interval, intermittent, low-intensity, slow-jogging program on skeletal muscle, fat infiltration, and fitness in older adults: randomized controlled trial

Masahiro Ikenaga[1] · Yosuke Yamada[2] · Yujiro Kose[3] · Kazuhiro Morimura[1] · Yasuki Higaki[1] · Akira Kiyonaga[1] · Hiroaki Tanaka[1] · Nakagawa Study Group

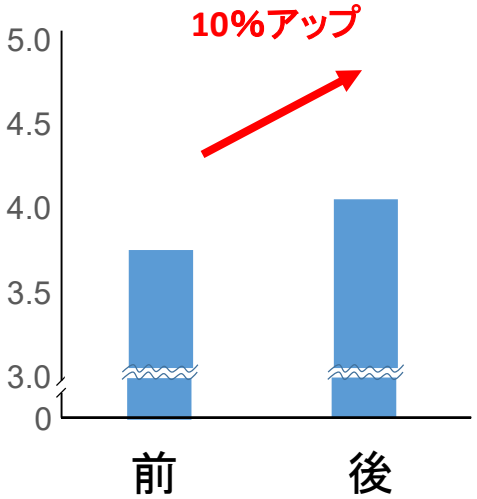
- 高齢者75名（70.8±4.0歳）
- 運動群（n=37），対照群（n=38）に無作為割り付け
- 12週間



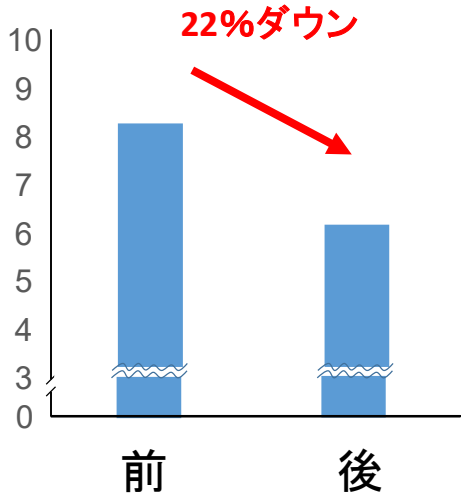
スタミナ力
（メッツ強度）



大腿部筋量
（細胞内水分量, kg）



大腿部脂肪面積
（cm²）



まとめ

- ✓ 細切れ運動や立ち上がり動作は、血糖のコントロールに有効な身体活動
- ✓ スロージョギングは、血糖コントロールに敷居の低い実行可能な運動