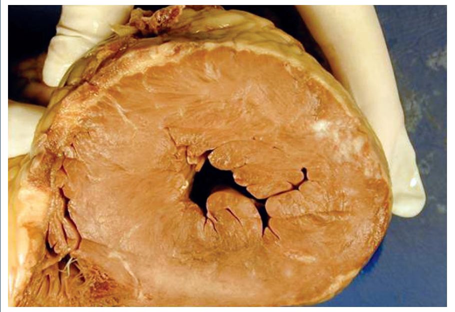

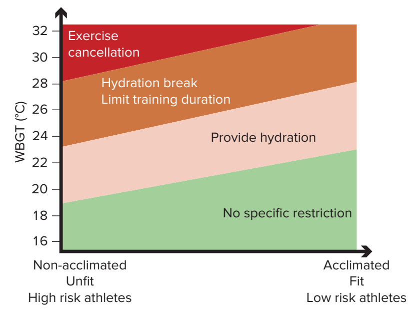


*Brukner & Khan's Clinical Sports Medicine*, the world-leading title in sport and exercise medicine, is an authoritative and practical guide to the complete care of people at all levels of physical activity. It is an ideal practical and reference text for physiotherapists, medical doctors, team clinicians, athletic trainers, sports therapists, sports rehabilitators and trainers, as well as students in the health professions and in Human Movement Studies.

To accommodate the rapid advances in the profession, this fifth edition has been expanded into two volumes. The first volume, *Injuries*, is the essential guide to all aspects of preventing, diagnosing and treating sports-related injuries. This second volume, *The Medicine of Exercise*, focuses on the health benefits of exercise and discusses the current medical issues in sport.

*The Medicine of Exercise* comprises 16 chapters from the fourth edition of *Clinical Sports Medicine,* comprehensively revised and rewritten, along with 24 new chapters.

The six sections of *The Medicine of Exercise* are:

- Physical activity and health (6 chapters)
- Managing medical problems (16 chapters)
- Exercising in challenging environments (5 chapters)
- Exercise medicine for specific groups (5 chapters)
- Performance and ethics (5 chapters)
- Practical sports medicine (3 chapters)

An ebook of *Clinical Sports Medicine: The Medicine of Exercise* is also available.


**PETER BRUKNER**
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Peter Brukner is a Sport and Exercise Physician and was the Australian cricket team doctor from 2012 to 2017. He was previously Head of Sports Medicine and Sports Science at the Liverpool Football Club in the UK. Peter is the founding partner of the Olympic Park Sports Medicine Centre, a past president of the Australasian College of Sport and Exercise Physicians, and Professor of Sports Medicine at La Trobe University. Peter has been an Olympic team physician and was the Socceroos team doctor at the 2010 World Cup. In 2005 he was awarded the Order of Australia medal (OAM) for services to sports medicine.


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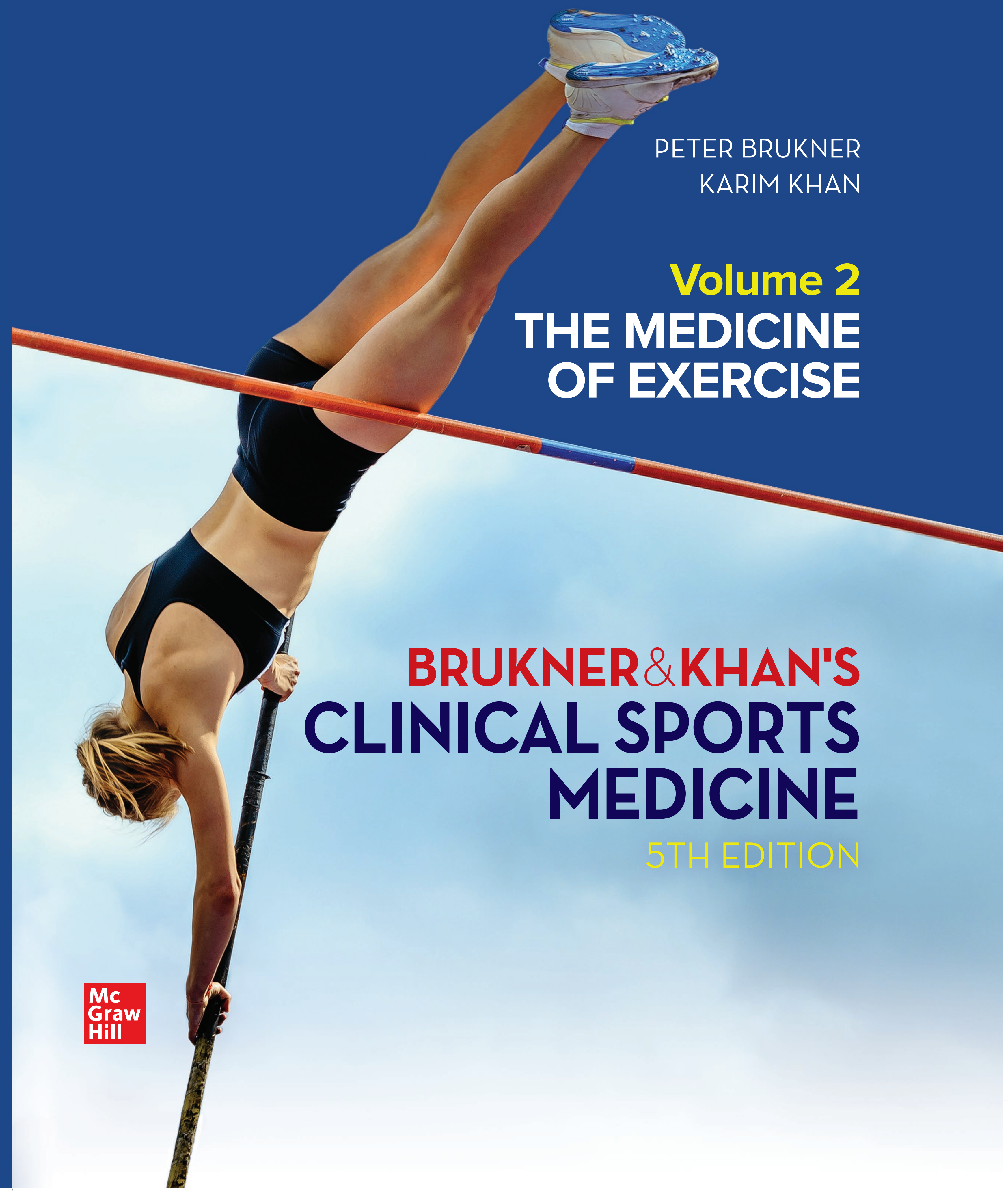
BRUKNER&KHAN'S CLINICAL SPORTS MEDICINE
5TH EDITION
Volume 2 THE MEDICINE OF EXERCISE


McGraw Hill


PETER BRUKNER
KARIM KHAN


## Volume 2
# THE MEDICINE OF EXERCISE

# BRUKNER&KHAN'S CLINICAL SPORTS MEDICINE

5TH EDITION


McGraw Hill

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# CLINICAL SPORTS MEDICINE

*We dedicate this fifth edition to the Clinical Sports Medicine community. We are proud to be in a family of clinicians who deliver quality patient care with passion.*

BRUKNER & KHAN'S

# CLINICAL SPORTS MEDICINE

## Volume 2
## THE MEDICINE OF EXERCISE

5TH EDITION

Peter Brukner
Karim Khan

McGraw Hill

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# Foreword to the first edition (1993)

Sport in Australia is ingrained in the national consciousness more widely, deeply and indelibly than almost anywhere else in the world. When a prominent sportsperson sustains a sporting injury, either traumatically or from overuse, becomes excessively fatigued, or fails to live up to expectations, this assumes national importance. It is even more relevant nowadays with greater individual participation in sporting activities. The same type of problems occur for recreational athletes, middle-aged people wanting to become fit, or older people wishing to sustain a higher level of activity in their later years.

In *Clinical Sports Medicine* the authors take sport and exercise medicine out of the realm of the elite athlete and place it fairly and squarely where it belongs–as a subspecialty to serve everyone in the community who wishes to be active.

The book is organised in a manner that is sensible and usable. The chapters are arranged according to the anatomical region of the symptom rather than diagnostic categories. This results in a very usable text for the sports physician, general/family practitioner, physiotherapist, masseur, or athletic trainer whose practice contains many active individuals.

Practical aspects of sports medicine are well covered–care of the sporting team and concerns that a clinician might have when travelling with a team. In all, this is an eminently usable text which will find an important place among clinicians involved in the care of active individuals.

John R Sutton MD, FRACP
*Professor of Medicine, Exercise Physiology and Sports Medicine*
*Faculty of Health Sciences*
*University of Sydney*
*Past President, American College of Sports Medicine*

*This foreword was written by the late Professor John Sutton before his untimely death in 1996; we honour the memory of this champion of the integration of science, physical activity promotion and multidisciplinary patient care.*

# Foreword

*To study the phenomenon of disease without books is to sail an uncharted sea, while to study books without patients is not to go to sea at all.*

–Sir William Osler

One of the pleasures of my professional life has been observing *Clinical Sports Medicine's* birth, adolescence and maturity over almost 30 years. In January of 1993, I held up high a copy of this first print-run, first edition, 697-page plain red book to the audience at the South African Sports Medicine Association (SASMA) Congress in Cape Town's Convention Centre.

I said that it was a revolutionary red book because it was very practical (symptom-oriented rather than pathology-based) and that with its five sections and 48 chapters, it propelled sports medicine beyond a narrow focus on athlete injury treatment (largely orthopaedic at that time). This red book defined what is now recognised as sport and exercise medicine–our specialty that provides comprehensive care (including prevention) for a much more inclusive constituency–any person who is active or who wants to be active. It was, as I already knew then, the book that would take an emerging yet immature discipline, across uncharted seas, to a land of hard science and clinical wisdom. Sport and exercise medicine could provide a beacon of all that is the very best in a patient-centred medical care, focusing on providing optimum health.

Fast forward to 2019, where Volume 2 of the fifth edition will again be waved aloft as a gold standard for clinicians who attend this year's South African Sports Medicine Association Congress. Each edition of *Clinical Sports Medicine* has clearly raised the educational bar in our specialty–each has provided substantially more value for the user, a word I use deliberately over 'reader'. Copies of this book are in tatters the world over because it is used! Now our field demands a two-volume fifth edition to do justice to the high quality science that now underpins our field. No more 'Mickey Mouse medicine'–a term one of my professors reserved for *sports medicine* in the 1980s.

*Volume 2: The Medicine of Exercise* provides some solutions for the global epidemic of non-communicable diseases (NCDs). It responds to *The Lancet's* 2012 and 2016 challenges in our field. As Richard Horton, the Editor, wrote: *We urge all sectors of government and society to take immediate, bold actions that help make active living a more desired, affordable, and accessible choice for all population groups.*

This dedicated volume of 40 chapters in six logical sections provides both the blueprint and the step-by-step instructions for clinicians to take 'immediate bold action'. Clinicians have a wonderful opportunity to limit–dare I say reverse–some of the noncommunicable diseases from which their patients now suffer in ever-increasing numbers. The reality is that the advice is fairly straightforward; it is hardly rocket science. Yet it is based on the best available scientific evidence for promoting active living and rational eating.

I don't apologise for my challenging this belief–that as physicians we have not done all that we can to advance the health of our patients. The 'why' we need to do this is clear to clinicians–we know we should encourage exercise and healthy eating–but it is the 'how' that has been difficult. This volume will help the clinician clear that barrier. Type 2 diabetes mellitus is just one condition that, we now know, can be reversed in the majority. And the 'how' is outlined in this volume.

It has been my privilege to be an author of *Clinical Sports Medicine* since the second edition (2001) and I have appreciated that opportunity to reach young clinicians the world over. Congratulations to my very dear friends, Professors Peter Brukner and Karim Khan, for their leadership in what was once a nascent field but one which through their passion, commitment, dedication, wisdom and scholarship they have raised to a level that none of us could have ever imagined when the first edition was launched in Melbourne in December of 1992.

Comparisons are of course odious but it is my opinion, and I do not offer it glibly, that future generations will conclude that what Sir William Osler's *Principles and Practices of Medicine* did for medicine in the 1890s, Brukner and Khan's *Clinical Sports Medicine* fifth edition will do for the practice of the profession of sport and exercise medicine globally.

That is how highly I rate the contributions of these two uniquely gifted and visionary sports physicians who have written what will always be, like Osler's *Principles and Practices*, an utterly iconic text. A statement for the ages.

Following their lead, the challenge for the rest of us is to implement and promote what we now know is society's best buy for public health–more physical activity and the replacement of 'the diet of modern commerce' with the consumption of the real foods that humans had always eaten before we were mistakenly told to change 40 years ago.

Volume 2 of *Clinical Sports Medicine* is an evidence-based compendium of how we, as clinicians interested in the perfectly functioning human, can help direct the world's populations toward states of greatly improved health.

That is the opportunity that this epic work of meticulous scholarship delivers.


Professor Timothy D Noakes
*OMS, MBChB, MD, DSc, PhD (hc), FACSM), (Hon), FFSEM (UK), (Hon), FFSEM (Ire)*
*Sports Physician and Exercise Physiologist*
*Former Discovery Health Professor of Exercise and Sports Science,*
*University of Cape Town and Sports Science Institute of South Africa*

# Brief contents

# Contents

## PART E PERFORMANCE AND ETHICS

Contents

## PART F PRACTICAL SPORTS MEDICINE

# Preface

Helping clinicians to help patients has been the clear focus of *Clinical Sports Medicine* from its inception. In this volume we bring you more authors, more practical tips and more evidence of the work we do as sport and exercise medicine clinicians. If you are a loyal member of the *Clinical Sports Medicine* community you will already know that we completed *Volume 1: Injuries* and then dedicated a fresh year of our lives to *Volume 2: The Medicine of Exercise*. It was a boon for us to be able to concentrate on Volume 2 because historically (pre-2000) the focus of sports medicine had been injuries, and the first four editions of *Clinical Sports Medicine* really reflected that bias.

As governments began to wrestle with the crippling cost of non-communicable diseases (NCDs) they found there was no magic medication or operation to turn to. Suddenly, sport and exercise clinicians–those erstwhile medical 'extras', who had been fighting for specialty status in the 1980s–moved to centre stage, working with the World Health Organization, national and state or provincial governments, and health insurers. Research funding agencies supported various studies of exercise for heart disease, diabetes, cancer and cognitive function. National sports medicine bodies, such as those in Britain, Canada and Australia (BASM, CASM, ACSP), all added an 'E' for Exercise in their titles (BASEM, CASEM, ACSEP). It is telling that the shorter versions now seem very dated. Sports Medicine without 'Exercise'? Weird!

## What's new?

*Clinical Sports Medicine* clearly needed a dedicated *Medicine of Exercise* volume to capture a decade of advances. So what's new in this Volume 2 of the fifth edition?

- *Our most comprehensive overview of exercise and physical activity medicine.*
- *19 totally new topics.* (See new content below.)
- *A practical focus and more detail.* The focus is one the practical elements of exercise prescription, with more tips, more practical tables and more illustrations.
- *Illustrated real-life patient stories.* We share lessons from the world's best athletes–their voices, their challenges and their clinicians' actions and tips.
- *More than 3000 references*–the solid foundation. Our chapter authors' clinical perspective is key, but what they share is founded on increasingly solid science.

## Chapter authors

***Volume 2*: *The Medicine of Exercise*** reflects the generosity of the 53 chapter authors and contributors from seven countries. Exercise medicine is arguably more diverse than injury medicine and we are grateful for their expert and enthusiastic contributions throughout chapters 1 to 40.

## New content

We feel this is the first true contribution to the field of sport and exercise medicine. The following new authors have shared their clinical experience, anchored in new evidence and gained over many years:

**Part A–Exercise for health** does precisely what it says on the tin! World Health Organization technical advisor and remarkable medical student (at time of publication) Daniel Friedman takes the helm, steering the reader on a journey from the problem of physical inactivity–and why clinicians need to address non-communicable diseases (Chapter 1), to the clear physiological benefits of activity at the cellular level (Chapter 2), through the how of assessing the patient (Chapter 3) and on to prescribing activity for him or her (Chapter 4). Keeping with our clinical focus, the part closes with tips for the clinician to complement training on motivational interviewing (Chapter 5). The final chapter (Chapter 6, Nutrition for health) reflects the fact that nutrition is now recognised as a vital key to health (in particular with respect to NCDs). Nutrition papers are now published in *The Lancet*, *The BMJ* and *JAMA*–and that was not the case when we launched the first edition of *Clinical Sports Medicine*.

**Part B–Managing medical problems.** Six completely new chapters and ten that have been totally revised from the fourth edition are included. There are new chapters on management of obesity (Chapter 7), osteoarthritis (Chapter 16), osteoporosis (Chapter 17), cancer (Chapter 20), depression (Chapter 21) and anxiety (Chapter 22). The other chapters in this part describe and illustrate how to manage critical conditions found in ten other medical specialty areas: diabetes, sports cardiology (two chapters), sports respirology, gastrointestinal, renal and urinary, neurological, rheumatological, infection, and the tired athlete.

**Part C–Environment.** World leaders, including Professors Mike Tipton and Michael Koehle as well as Drs Sébastien Racinais and Olaf Schumacher, share decades of experience in this domain. Heat (Chapter 23), Cold (Chapter 24), Altitude (Chapter 25) and Underwater (Chapter 26) are substantial upgrades on their fourth edition counterparts. Physical activity and the built environment (Chapter 27) is a completely new chapter; the built environment is one of the World Health Organization's Seven Investments for Better Health.

**Part D–Specific groups.** These five chapters focus on the very young (Chapter 28, Associate Professor Carolyn Broderick), girls and women (Chapter 29), older people (Chapter 31) and The person with disability (Chapter 32). Completely new too is the complex issue of transgender and intersex. What endocrine pathways underpin the biology? When is it fair for a transgender athlete to compete? Does hyperandrogenism confer an unfair advantage? Dr Liesel Geertsema provides a very balanced view, as there are no easy answers (Chapter 30).

**Part E: Performance and ethics.** Four new chapters among five potentially contentious ones: nutrition for performance (new, Chapter 33), drugs in sport (Chapter 34), genetics in sport including genetic testing (new, Chapter 35), legal issues (new, Chapter 36), and harassment and abuse (new, Chapter 37) by Canadian professor and IOC Medical Commission member Dr Margo Mountjoy.

**Part F–Practical sports medicine.** The new chapter here is on multisport endurance events (Chapter 40), by veteran and international leader Professor Paul Auerbach. Emergency medicine for the sideline clinician is covered in detail and helpfully illustrated (Chapter 38). Professor Timothy Noakes provides the latest from his four-decade experience of endurance event medicine (Chapter 39).

*We are delighted with how* Volume 2: The Medicine of Exercise *has turned out and for that we thank the champion team of multidisciplinary authors who so generously committed to sharing their expertise. They have provided an invaluable resource for our community.*

# About the authors

## Peter Brukner

OAM, MBBS, DRCOG, FACSEP, FASMF, FACSM, FFSEM (Ireland, Hon), FFSEM (UK, Hon)

### Sport and Exercise Medicine physician

Professor of Sports Medicine, La Trobe University, Melbourne, Australia

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Associate Professor, Centre for Health, Exercise and Sports Medicine, The University of Melbourne, Australia

Honorary Fellow, Faculty of Law, The University of Melbourne, Australia

Adjunct Professor, School of Human Movement Studies, The University of Queensland, Australia

Adjunct Professor, Liverpool John Moores University, UK

Visiting Professor, Lee Kong Chian School of Medicine, Singapore

Visiting Associate Professor, Stanford University, USA 1997

Executive Member, Australian College of Sports Physicians 1985–2000

President, Australian College of Sports Physicians 1991–92, 1999–2000

Board of Trustees, American College of Sports Medicine 2000–02

State and Federal Council Member, Sports Medicine Australia 1984–90

### Team physician

Team Doctor, Australian cricket team, 2012–17

Head, Sports Medicine and Sports Science, Liverpool Football Club, UK 2010–12

Socceroos 2007–10, Asian Cup Finals 2007, World Cup Finals 2010

Australian Olympic Team, Atlanta 1996, Sydney 2000

Australian Commonwealth Games team, Edinburgh 1986, Kuala Lumpur 1998

Australian team, World Student Games, Edmonton 1983, Kobe 1985, Zagreb 1987

Australian Athletics team 1990–2000, World Championships Tokyo 1991, Gothenburg 1995, Seville 1999

Australian team, World Cup Athletics, Havana 1992

Australian Men's Hockey team 1995–96

Australian team, World Swimming Championships, Madrid 1986

Melbourne Football Club (AFL) 1987–90

Collingwood Football Club (AFL) 1996

### Books (co-author)

*Food for Sport* 1987

*Stress Fractures* 1999

*Drugs in Sport—What the GP Needs to Know* 1996, 2000

*The Encyclopedia of Exercise, Sport and Health* 2004

*Essential Sports Medicine* 2005

*Clinical Sports Anatomy* 2010

*A Fat Lot of Good* 2018

### Editorial boards

*British Journal of Sports Medicine*

*Clinical Journal of Sport Medicine*

*Current Sports Medicine Reports*

*The Physician and Sportsmedicine*

### Editor

*Sport Health* 1990–95

### Awards

Medal of the Order of Australia 2006

Inaugural Honour Award, Australian College of Sports Physicians 1996

Citation Award, American College of Sports Medicine 2000

Honorary Fellowship, Faculty of Sports and Exercise Medicine (Ireland) 2012

## Karim Khan

MD, PhD, MBA, FACSEP, FSMA, DipSportMed (CASEM), FACSM, FFSEM (Ireland, Hon), FFSEM (UK, Hon)

### Sport and Exercise Medicine physician

Professor, University of British Columbia (Department of Family Practice and School of Kinesiology), Vancouver, Canada

Scientific Director, Canadian Institutes of Health Research (CIHR)—Institute of Musculoskeletal Health and Arthritis (IMHA).

Adjunct Professor: Professor, School of Allied Health, College of Science, Health and Engineering, La Trobe University, Melbourne, Australia

Visiting Professor, School of Human Movement Studies, The University of Queensland, Brisbane, Australia

Clinical Professor, Centre for Musculoskeletal Studies, School of Surgery, University of Western Australia, Perth, Australia

Co-Director, Centre for Hip Health and Mobility, University of British Columbia, Vancouver, Canada, 2016–17

Medical Education Committee, American College of Sports Medicine 2002–04

Research Evaluation Committee, American College of Sports Medicine 2005–07

Exercise is Medicine Committee, American College of Sports Medicine 2009–11

Advisory Board to the International Olympic Committee 2015–

Director of Research and Education, Aspetar Orthopaedic and Sports Medicine Hospital, Qatar 2013–15

### Team physician

Olympic Games Sydney 2000, Basketball Competition Venue

Australian Women's Basketball (The Opals) 1991–96

The Australian Ballet Company 1991–96

The Australian Ballet School 1991–96

Australian team, World Student Games 1993

Australian team, Junior World Cup Hockey 1993

### Editor-in-chief

*British Journal of Sports Medicine* 2008–20

*BMJ Open Sport and Exercise Medicine* 2015–18

*Sport Health* 1995–97

### Books (co-author)

*Physical Activity and Bone Health* 2001

*The Encyclopedia of Exercise, Sport and Health* 2004

### Editorial boards

*The BMJ* (International Advisory Board) 2008–14

*Scandinavian Journal of Medicine and Science in Sport* 2007–10

*British Journal of Sports Medicine* (North American Editor) 2005–07

*Journal of Science and Medicine in Sport* 1997–2001

*Year Book of Sports Medicine* 2008–10

*Clinical Journal of Sport Medicine* 2003–06

### Selected awards

Prime Minister's Medal for Service to Australian Sport 2000

Sports Medicine Australia Fellows' Citation for Service 2005

Honorary Fellowship, Faculty of Sports and Exercise Medicine (Ireland) 2011

Honorary Fellowship, Faculty of Sport and Exercise Medicine (UK) 2014

Honorary Doctorate, NIH, Oslo (Norway) 2018

Honorary Doctorate, University of Edinburgh (UK) 2019



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# Editors

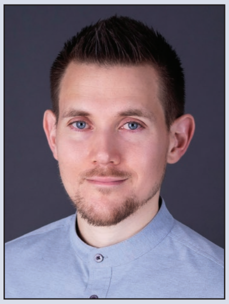
*In the writing of this Volume 2 of our fifth edition, we were very fortunate to have the assistance of two outstanding young writers, Daniel Friedman and Paul Blazey. Their contribution has been massive and we could not have done it without them. Heartfelt thanks!*

**Daniel Friedman** MBBS (Hons) (2019e)

Daniel Friedman is a final year medical student from Monash University in Melbourne, Australia, with a keen interest in sport and exercise medicine. Daniel has completed medical training across rural Victoria and undertook an unusually high volume of shadowing leading sports medicine physicians in the clinic. After completing an internship for the World Health Organization (WHO) in 2017 in the non-communicable disease prevention program, Daniel served as a technical advisor to the WHO on physical activity, and assisted with development of the *Global Action Plan on Physical Activity 2018-30* and *ACTIVE Technical Package*.

Daniel is currently leading the development of the WHO's physical activity counselling toolkit, which aims to provide global best practice solutions to integrate physical activity into routine clinical practice. Daniel is also an Associate Editor and Podcast Editor for the *British Journal of Sports Medicine* (BJSM). He has covered conferences around the world for the BJSM, and is a regular contributor to the journal's blog. Daniel loves most sporting activities—running, swimming and, cycling, basketball and tennis.

**Paul Blazey** BSc (Hons) Physiotherapy, PGCert Healthcare Education



Paul worked as a specialist musculoskeletal physiotherapist with the National Health Service (UK) and in sports-specific roles with Crystal Palace and Arsenal FC academy. He owned Freeflex Physio, a clinic run in conjunction with the University of East Anglia, that provided specialist sports physiotherapy services to students and athletes. He is an experienced teacher who worked at both the University of East Anglia and Health Education England. As well as teaching specific clinical physiotherapy courses, he was responsible for education governance and quality.

Paul moved to Vancouver, Canada, in 2017 to take up a role with the University of British Columbia and works clinically with athletes out of the Restore Physiotherapy Clinic with Dr Chris Napier. He is also part of the editorial team for the *British Journal of Sports Medicine.* Paul is an accomplished distance runner with a personal best of 2 hours 39 minutes over the marathon distance and he is interested in health promotion, injury prevention and the use of wearable technology within sport and everyday physical activity.

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# Acknowledgements

*If you want to go fast, go alone. If you want to go far, go together.*
–African proverb

How long is a generation? As we two authors are about to shut our laptops on Edition 5, Volume 2, we reflect on the longer arc of the privilege and opportunity this book has afforded us. *Clinical Sports Medicine* was conceived in 1991 (OK Peter, I admit it was your idea. I have never denied that and yes, now it's in print–K2). In 2019, we have 28 years of thanks to give to over 500 contributors to five editions and what is essentially six books now. That's a generation of sport and exercise medicine clinicians and scientists; a female generation is currently 25.5 years. Note that we have become more evidence-based as we have aged–*lifelong learners!* The first edition of *Clinical Sports Medicine* had zero references and the authors had three publications between them (3 and 0, respectively).

We thank those who went far with us on what we hope has been a worthwhile journey over the 28 years. Some have been part of the *Clinical Sports Medicine* convoy from day 0 – a dinner at Sukhothai Restaurant in Johnston Street, Collingwood, Melbourne. Others joined later and provided one or more of those pearls that are so valued by the clinicians we speak to the world over. We thank every contributor on behalf of every clinician who has flicked through the pages of *Clinical Sports Medicine* to help the patient either in front of them or just out of sight.

For this fifth edition, *Volume 2:The Medicine of Exercise*, specific thanks go to the 53 chapter co-authors listed, with their affiliations, on pages xxix–xxxi. Because we wanted the world expert in every area to contribute to that chapter, very few authors contributed more than one chapter. That is a strength of this book–many subspecialist authors had their work woven together. The beauty of writing Volume 1 and Volume 2 across two years meant that we two authors could focus on the 'medicine of exercise' in a way that was impossible in a one-volume book. That's a compelling case for going far more slowly but ultimately with more support–more co-authors–than in the four single-volume editions. This two-volume edition brings you 48 and 40 chapters (88 in total) with 200 chapter authors–almost twice the number that built the 4th edition.

When one goes far together there is scope for all generations to contribute. The young bring curiosity, passion, vigour and stamina as well as innovation and facility with technology and platforms. We thank and applaud clinicians Paul Blazey (sports physiotherapy) and Daniel Friedman (medicine) for being editors across all chapters in Volume 2. You made 2018 not only productive but also a rich year in our lives. We often hear emerging talents thanking 'mentors'–here we spell out the reciprocity of our relationship. We learned many things from you, and you introduced us to scintillating people who enliven our community. We will follow your bright trajectories with joy.

*Find a job you enjoy doing, and you will never have to work a day in your life.*
–Mark Twain

Taking the long view of gratitude again, we authors have been privileged to work in our vocation. Being a clinician is a gift, and being researchers and teachers as well means we are triply fortunate. We thank those who trusted us to be so privileged in university, college (e.g. Australasian College of Sport and Exercise Physicians), journal, media and sport team/federation settings. We hope we have lived up to the expectations of those who punted on us.

One closing paragraph on our first and very special *Volume 2: The Medicine of Exercise*. We thank all of you who had the vision that exercise and physical activity truly is the polypill. You kept working to test your hypothesis–that exercise is medicine–with equipoise. You are unsung heroes who demonstrated the benefits of exercise across organ systems (cardiovascular, respiratory, neurological) and in various populations (older people and kids, those living with diseases/disorders, those with disabilities, those who are marginalised). You are working in knowledge translation, implementation and scale-up. You provided the bedrock for this volume.

We are grateful to all those who have trusted us–patients and athletes, coaches, colleagues, trainees, readers. We are grateful to have been entrusted with leadership positions with their privileges and responsibility. Our simple hope is that we have added value to our remarkable community that goes far to help patients and athletes 24/7 and 365. A community that allows the world to benefit from physical activity, exercise and sport.

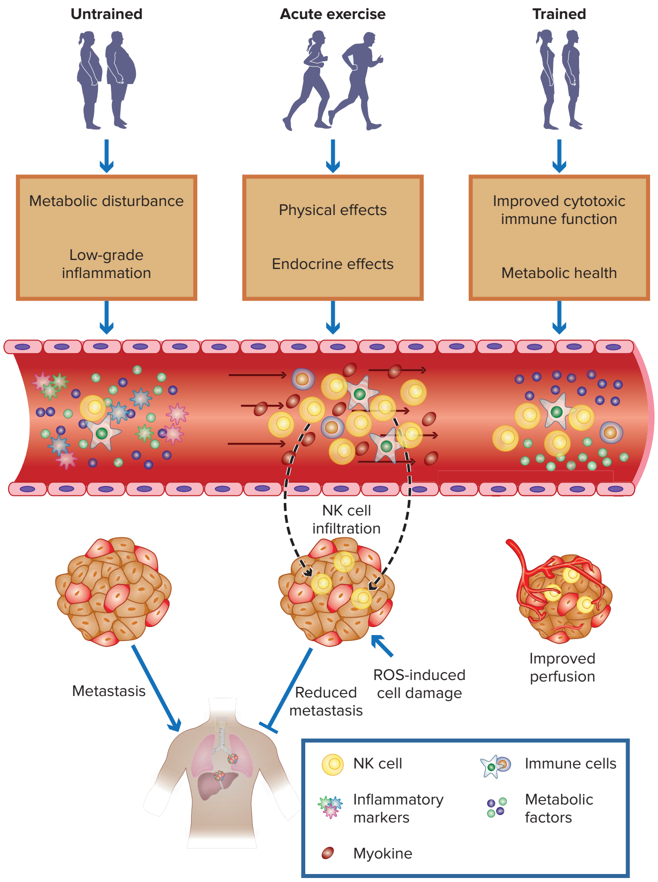
# Guided tour of your book

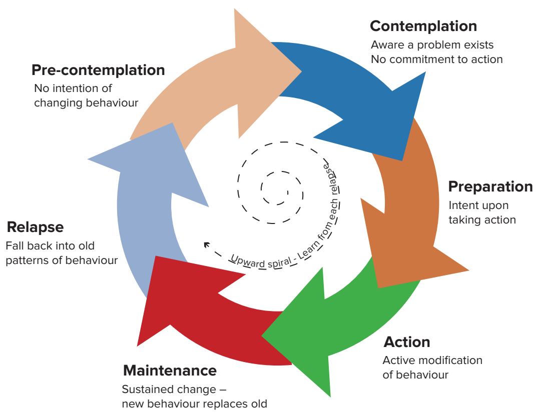
**The principal text in its field, this second volume of the fifth edition of *Clinical Sports Medicine* continues to provide readers with quality up-to-date content. The engaging material has been contributed by leading experts from around the world. Look out for these key features, which are designed to enhance your learning.**

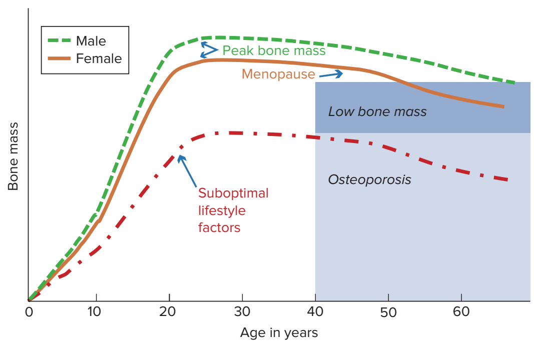
## Premium, up-to-date content

PART A EXERCISE AND HEALTH discusses the global public health problem of physical inactivity and includes a chapter on nutrition. PART B MANAGING MEDICAL PROBLEMS considers the effect of activity levels on the most common medical issues, such as obesity, diabetes and cancer, as well as others. PART C ENVIRONMENT focuses on the effects of heat, cold, altitude and being underwater on the athlete and includes a chapter on the built environment and its influence on activity levels. PART D SPECIFIC GROUPS includes issues relating to treating children, older people and people with disability and discusses female-specific and transgender and intersex issues in sport. PART E PERFORMANCE AND ETHICS discusses nutrition for performance, legal issues, genetics, harassment and abuse, and drugs and the athlete. PART F PRACTICAL SPORTS MEDICINE provides best practice medical advice regarding emergencies and endurance events, including multisport endurance events.

These topics are discussed via clear text, abundant clinical and other photos and relevant imaging. New data is obtained from research published in peer-reviewed journal articles and the reader is directed to the online references for further information. Tables and diagrams throughout illustrate the key concepts.



## Tables

New tables summarise vast amounts of evidence to provide take-home messages. Primary sources are readily available.

**Table 6.1 Types of amino acids**

| Essential | Conditionally essential | Non-essential |
|---|---|---|
| Histidine | Arginine | Alanine |
| Isoleucine | Cysteine | Aspartic acid |
| Leucine | Glutamine | Asparagine |
| Lysine | Glycine | Glutamic acid |
| Methionine | Proline | Serine |
| Phenylalanine | Tyrosine | |
| Threonine | | |
| Tryptophan | | |
| Valine | | |

## Case studies

**Case studies** provide real-world examples of issues discussed in the chapter.

**CASE STUDY**

**Rob Waddell, rower—atrial fibrillation**

*Competing at the highest level of sport is hard enough without throwing a whole other variable into the mix. I used to be really scared every single race that I would have an episode of AF.*

Rob Waddell (Fig. 10.4) was an elite-level rower for New Zealand, winning the world single sculls titles in 1998 and 1999, before capturing Olympic gold in the same discipline at the Sydney Olympics in 2000. He also held the world record for indoor rowing at both 2000 and 5000 metres.

**Diagnosis**

In the 1990s Waddell experienced a significant loss in power output, breathlessness and extreme fatigue both during training and racing.

A Holter monitor was used to assess his heart rhythm over an extended period of time, however the results were inconclusive. Waddell was sent to Auckland for electrophysiologic testing (See Need to Know box below.) He was subsequently diagnosed with paroxysmal atrial fibrillation (AF).

**Management**

Despite treatment with high dose flecainide in an attempt to control his AF, the condition persisted, becoming increasingly more severe and intrusive throughout his career, particularly in the lead-up to the 2000 Olympics in Sydney.

Following his victory at the Sydney Olympics, Waddell decided to change sports and shift his focus to sailing, given the ongoing difficulty of managing his AF. The change in sports necessitated a 20 kg weight gain and, due to the more intermittent nature of the activity, Waddell was able to compete relatively asymptomatically and even stop taking flecainide.

In 2008, Waddell decided to return to rowing. During the deciding race of a best-of-three series that determined

**Figure 10.4** Rob Waddell on the podium at the 2000 Sydney Olympics
GETTY IMAGES/PHIL WALTER

qualification for the Beijing Olympics, Waddell suffered a recurrence of his AF. He vividly described the experience as feeling 'like rowing through mud'. Waddell went on to qualify for the Beijing Olympics and placed fourth in the double sculls.

Waddell would later undergo radiofrequency ablation which dramatically improved his AF and enabled him to continue sailing competitively at the international level.

**Conclusion**

Waddell's story provides a good example of a common problem faced by elite competitors with AF. With appropriate and careful management, athletes with AF may still be able to compete in their sport at the highest level.

## Boxes

**Boxes** throughout the chapters focus on specific topics.

**The Blue Zones: dietary patterns of longevity**

The 'Blue Zones', a term coined by *National Geographic* writer Dan Beuttner in 2005, are regions of the world where people live much longer than average. Buettner has identified five Blue Zones: Okinawa (Japan), Sardinia (Italy), Nicoya (Costa Rica), Icaria (Greece) and among the Seventh-day Adventists in Loma Linda, California (USA).

People living in these regions all share common lifestyle characteristics, such as social and family engagement, constant moderate physical activity throughout the day and not smoking.[304]

Although these factors, as well as genetics, may confound the impact of diet on their impressive longevity, their diets are remarkably similar and are based on common principles, including:

- moderate caloric intake
- moderate alcohol intake, mostly red wine; drink mostly water and tea
- whole foods plant-based, semi-vegetarian diet with very limited meat, fish, and sheep's or goats milk cheeses
- daily consumption of food from healthy fat sources, such as olives and nuts
- daily consumption of legumes
- no refined carbohydrates or added sugars.

The Blue Zones demonstrate an established theme of healthy eating, relevant across generations and geographical borders that could, theoretically, have a profound influence on public nutrition and dietary guidelines.

## Co-authors

The 53 **world-renowned co-authors** bring a truly global perspective to the book.

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## Practice pearls and Need to know

**Practice pearls** are a valuable feature that provide clinical tips and important information to keep in the forefront of your mind.

**PRACTICE PEARL**

Warning symptoms such as exercise-related syncope must be carefully evaluated to rule out potentially lethal cardiac disorders.

**NEED TO KNOW**

Those involved in sports where making weight is important, such as power lifting, boxing and wrestling, may consider omitting insulin, to support a reduced weight at weigh-in.[25] Education should always be the primary concern of the medical professional involved with these athletes, including the implications for their health and potentially performance.[26]

## References

Over 3000 carefully chosen references. A comprehensive list of references for each chapter can be found here: **www.mhhe.com/au/CSM5e.**



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PART A

# Exercise and health

Chapter 1

# Physical inactivity: a global public health problem

with Daniel Friedman

*I believe that evidence supports the conclusion that physical inactivity is one of the most important public health problems of the 21st century, and may even be the most important.*

Professor Steven N Blair, Arnold School of Public Health, University of South Carolina, USA

Read any blog, newspaper, journal article or social media feed and you will find they are all telling you the same thing: physical inactivity is a problem–a big one. Physical inactivity causes alarming levels of chronic disease now; and the future predictions of societal costs and decimated quality of life are dire.

This is not new information. There have been calls to address the problem for decades. Global action plans and national strategies declared war on physical inactivity long ago, yet it seems many countries are still struggling to mobilise the troops. How many more times do we need to be reminded that physical inactivity is one of the leading risk factors for global mortality and is estimated to cause 3.2 million deaths annually,[1] before we finally decide to get off the couch?

The four previous editions of *Clinical Sports Medicine* shone a spotlight on the burden of physical inactivity and sedentary behaviour, but clinicians also appreciate the importance of other pressing behavioural contributors to health. As the World Health Organization (WHO) reminds us, unhealthy eating habits, tobacco consumption and harmful use of alcohol contribute to the tsunami of non-communicable disease (NCD). The concern, as Professor Steven Blair underlined so clearly in 2009, is that 'the crucial importance of physical activity is undervalued and underappreciated by many individuals in public health and clinical medicine'.[2]

To raise awareness and provide the clinician with even more motivation to promote physical activity to their patients, family and friends, this chapter records the economic and health costs of physical inactivity. We outline some of the key policies and actions that could reverse downward trends. A global health problem of this magnitude demands a calculated, methodical and consistent plan of attack. To make progress we must first understand the problem.

## PHYSICAL INACTIVITY TRENDS

The WHO Global Recommendations on Physical Activity advise that adults should do at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic physical activity throughout the week. Additionally, muscle-strengthening activities should be done at least twice weekly.[3] While there are no global recommendations on sedentary behaviour, emerging consensus indicates it should be limited whenever possible.[4]

From an evolutionary perspective, humans are primed to move; daily hunting and gathering for survival necessitated continual movement and exertion. However, today, many in the wealthy West no longer need to run, climb or even walk to procure food and water (Fig. 1.1). Everything is available at the touch of a button.

The rapid development of technology has engineered physical labour out of most of our lives. In the 1960s, almost half of private industry occupations in the USA required at least moderate intensity physical activity and now fewer than 20% demand this level of activity.[5]

Global estimates[6] indicate that:

- 31% of adults are physically inactive; 34% of women and 28% of men
- 80% of 13–15 year olds are physically inactive; girls are less active than boys
- physical inactivity is more common in countries of high income than in those of low income
- physical inactivity increases with age
- the proportion of adults spending four or more hours per day sitting is 42%.

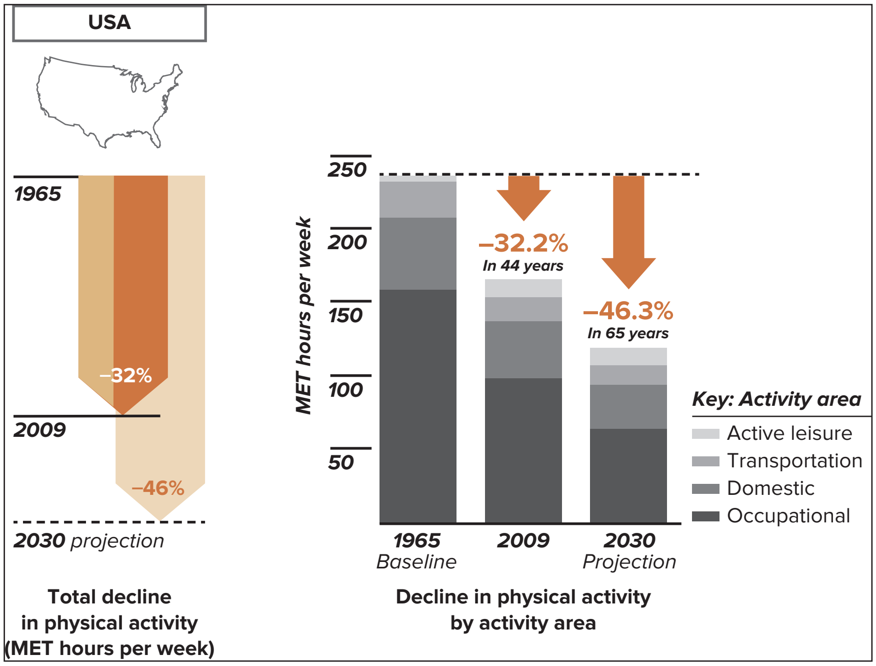


**Figure 1.1** Figure 1.1 Historic and projected physical activity levels: the dramatic reduction in physical activity in the United States. One metabolic equivalent (MET) is defined as 1 kcal/bodyweight kg/hour and is roughly equivalent to the energy cost of sitting quietly

ADAPTED FROM 'DESIGNED TO MOVE' (P.3), ACSM/NIKE WWW.RACKCDN.COM/RESOURCES/PDF/EN/FULL-REPORT.PDF

## THE COSTS OF PHYSICAL INACTIVITY

Direct healthcare costs of physical inactivity combine with indirect costs (productivity losses due to morbidity and premature mortality etc.) to contribute to a hefty physical inactivity price tag that affects society and ultimately individuals through poor health.

### Healthcare costs

Physical inactivity is responsible for approximately 30% of cardiovascular disease, 27% of diabetes, and 21-25% of breast and colon cancer.[7] The overall direct healthcare costs of physical inactivity can be calculated by estimating the proportions of diseases that can be directly attributable to physical inactivity, multiplying those by the relative risks for different diseases associated with physical inactivity and applying economic cost estimates from the healthcare system for treating the associated chronic diseases.

In 2013, the total direct healthcare cost of physical inactivity attributable to five major NCDs was US$53.8 billion:[8]

- $5 billion was spent on coronary heart disease
- $6 billion on stroke
- $37.6 billion on type 2 diabetes
- $2.7 billion on breast cancer
- $2.5 billion on colon cancer.

This estimate does not include costs attributable to musculoskeletal conditions, falls or depression and

**Table 1.1** Costs attributable to physical inactivity by country in 2013 (US$ million)

| Country | Direct costs | Indirect costs | Total |
|---|---|---|---|
| Australia | 442 | 114 | **556** |
| Canada | 946 | 182 | **1 129** |
| New Zealand | 107 | 31 | **138** |
| UK | 1 850 | 558 | **2 408** |
| USA | 24 733 | 3 059 | **27 793** |

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anxiety, and is limited by availability of country data. All of these costs (Table 1.1) are shared among governments, through public and private healthcare, and by patients who are forced to make out-of-pocket payments.

According to 2017 data, if all Australians did an extra 15 minutes of brisk walking for at least five days each week, Australia's physical inactivity disease burden would be reduced by 13%.[9] In other words, Australians could save nearly A$60 million in healthcare dollars every year by simply going for a stroll!

**NEED TO KNOW**

If physical inactivity were not eliminated, but could be decreased instead by 10% or 25%, more than 533 000 or 1.3 million deaths, respectively, would be avoided each year.[10]

## Productivity costs

The burden of physical inactivity extends well beyond healthcare dollars (Table 1.2). Indirect costs (Fig. 1.2) that are not often considered include productivity losses due to premature mortality, disability, absenteeism, presenteeism (employees who come in to work but have compromised productivity due to ill health), as well as informal care and other non-medical costs.

- In Canada, osteoarthritis is projected to cost C$18 billion a year in lost productivity by 2031, as the condition causes substantial long-term absenteeism and disability, reduced employment and early retirement.[11]
- In Australia, the national impact of diabetes through lost labour-force participation of people aged 45–64 years is projected to reach A$807 million in lost income, $350 million in extra welfare payments, $166 million in lost taxation revenue and $3 billion in lost gross domestic product (GDP) by 2030.[12]
- In the USA, obesity-attributable absenteeism among employees costs over US$8.5 billion per year.[13]

In 2013, the total cost of productivity losses from physical inactivity-related deaths worldwide was US$13.7 billion. Of this, $3.2 billion was in North America and $3.8 billion was in Europe. When these indirect costs are combined with the direct healthcare costs,

**Table 1.2** **Counting the cost of inactivity in Australia in 2013 (in A$)**

| Costs | |
|---|---|
| Healthcare expenditure | $ 640 million |
| Loss in productivity | $ 165 million |
| Loss in tax revenue through public healthcare expenditure | $ 425 million |
| Total amount paid by private sector (e.g. health insurance companies) for physical inactivity-related diseases | $ 91 million |
| Total amount paid out-of-pocket by households for physical inactivity-related diseases | $ 124 million |
| **Total cost** | **$1.45 billion** |

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| | Total spend (US$) in 2008 | 2008 Direct costs | 2008 Indirect costs | 2030 Direct costs projection | % Increase in direct costs 2008–2030 |
|---|---|---|---|---|---|
| USA  | $147.0b — OR — ~2× the federal budget for the Department of Education (based on US$77.4b 2012 budget) | $90.1b | $56.5b | $191.7b | ↑113% |
| UK  | $33.0b — OR — Close to the National Health Service's annual efficiency target (based on £20b of annual efficiency savings over the next four years) | $16.1b | $16.7b | $26.0b | ↑61% |

**Figure 1.2** Direct and indirect costs of physical inactivity in the past and as predicted for the future (US$)
ADAPTED FROM 'DESIGNED TO MOVE' (P. 9), ACSM/NIKE

A

## The costs of physical inactivity versus smoking

Yes, physical inactivity is extremely costly. But how does it compare with other risk factors for poor health, such as smoking? In 2012, the total healthcare expenditure due to smoking was US$467 billion, or 5.7% of global health expenditure. When including indirect productivity costs, the total economic cost of smoking totalled US$1.9 trillion.[15] This seems like it is exponentially greater than the cost of physical inactivity, until you crunch the numbers.

Let's use Canada as an example. In 2013, the total economic burden attributable to smoking in Canada was C$18.7 billion.[16] For each of the 5.7 million smokers in Canada in 2013,[17] these costs represent approximately $3280 in total expenditure per smoker.

Compare this to the total economic burden attributable to physical inactivity in Canada in 2013, which was $10.8 billion.[16] In 2013, four out of five Canadians did not meet the recommended physical activity guidelines,[18] which is 28.13 million out of 35.16 million people. Therefore, the per person cost of physical inactivity in Canada in 2013 was $10.8 billion divided by 28.13 million, or $384—an amount equivalent to roughly one ninth of the attributable cost per smoker.

Now consider that the average smoker in Canada consumes 14 cigarettes per day,[19] or 98 per week. If we assume a linear relationship, the attributable cost per inactive Canadian mirrors the total economic burden of smoking 11 cigarettes per week. Therefore, according to our assumptive back-of-the-envelope calculations, the cost of physical inactivity in Canada is approximately that of smoking about half a pack of 20 cigarettes per week.

physical inactivity is estimated to be responsible for $67.5 billion in costs worldwide (Table 1.3).[8]

These costs are distributed unequally and disproportionately throughout the world. High-income countries carry a larger proportion of the economic burden and low- and middle-income countries suffer a larger proportion of the disease burden.[8]

### Quality of life

Physical inactivity and subsequent ill health limits the degree to which we can enjoy the important possibilities of our lives. This subjective concept can be quantified

**Table 1.3 Total economic cost of physical inactivity attributable to five major NCDs in 2013 (US$ billion)**

| Costs | |
|---|---|
| Direct | $53.8 |
| Indirect | $13.7 |
| **Total** | $67.5 |

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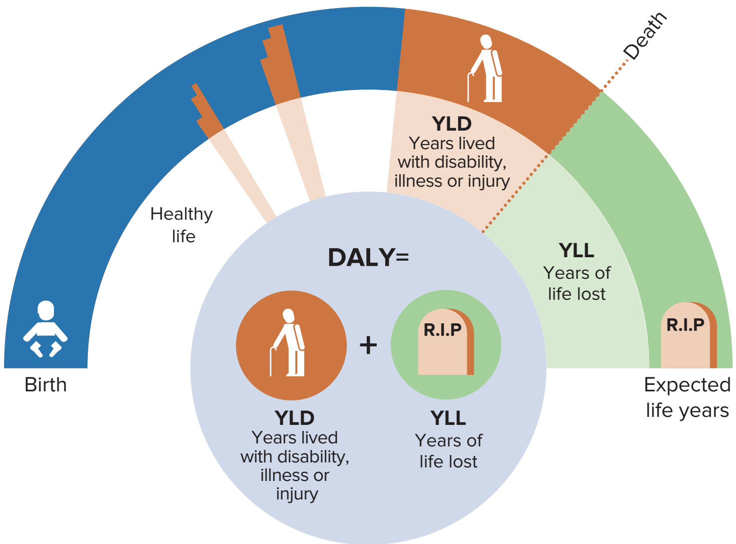


**Figure 1.3** The concept of disability-adjusted life years (DALYs) and its components

using disability-adjusted life years (DALYs) (Fig. 1.3). One DALY can be thought of as one lost year of 'healthy' life. Therefore, the sum of DALYs, or burden of disease, across the population can be thought of as a measure of the gap between current health status and an ideal health situation, where the entire population lives to an advanced age, free of disease and disability.[14]

In 2013, the lifetime disease burden associated with physical inactivity for the major NCDs was 13.4 million DALYs worldwide.[8]

## THE WAY FORWARD

If we continue to remain on the couch, the global burden of physical inactivity will continue to gain weight, particularly in low- and middle-income countries. There are obviously economic and health arguments for solving the physical inactivity pandemic, but what exactly needs to be done?

Given the diversity of ways to be active and the multiple settings in which we must look to increase participation, the solution to physical inactivity lies beyond the scope of any single agency. As the WHO's Global Action Plan on Physical Activity 2018–2030 (GAPPA)[20] emphasises, a major reduction in the burden of physical inactivity and subsequent NCDs will come from a whole-of-system approach which implements effective population-wide interventions that address both upstream and downstream factors of participation.

The '7 Best Investments for Physical Activity' from the International Society for Physical Activity and Health, in 2011,[21] captured this multidimensional approach, which has been revitalised in the most recent GAPPA. Both promote common key action areas, including:

- the built environment and transport (Chapter 27)
- schools and other educational institutions
- community and grassroots-based initiatives
- sports systems and programs
- public education
- healthcare
- advocacy and leadership
- monitoring and surveillance.

Every one of us must do our part to increase physical activity in all areas of society. We must find ways to integrate physical activity back into our daily lives through implementation of effective evidence-based policy actions that make the healthier choices easier.

Physical inactivity's costs, whether human or economic, direct or indirect, are entirely preventable. Armed with an understanding of the size and consequences of the problem, it is clear that the time for action is now.

### NEED TO KNOW

**WHO's Global Action Plan on Physical Activity 2018–2030: proposed targets for 2025**

25% reduction of premature mortality from NCDs
+
10% relative reduction in the prevalence of insufficient physical activity

## REFERENCES

References for this chapter can be found at www.mhhe.com/au/CSM5e

Chapter 2

# Benefits and risks of physical activity

with DANIEL FRIEDMAN

*Eating alone will not keep a man [or woman] well;*
*he [or she] must also take exercise.*

Hippocrates (460–370 BCE)

Physical activity is good for us. Well before the age of double-blind randomised placebo-controlled trials and peer-reviewed journals, Hippocrates and others espoused the benefits of exercise on the body and mind. Herodicus (400 BCE), a former teacher of Hippocrates and regarded as the pioneer of sport and exercise medicine, devoted his time to recommending exercise to help recovery from athletic and gymnastic injuries. Later, Galen (131–201 BCE), a Greek physician to the gladiators, proclaimed that 'the form of exercise deserving our attention is therefore that which has the capacity to provide health of the body, harmony of the part and virtue in the soul and these things are true of the exercise with the small ball'.

Fast forward a few thousand years and we have proof of many benefits of physical activity and reduced sedentary behaviour. Empirical evidence that physical activity was associated with health came in the 1950s. Dr Jerry Morris, a Scottish epidemiologist credited as 'the man who invented exercise', established the importance of physical activity in preventing cardiovascular disease after noticing that sedentary drivers of London's double-decker buses had higher rates of cardiovascular diseases than did the conductors who climbed the stairs. 'Is this chance a phenomenon?' asked Morris in his 1953 *Lancet* paper.[1] He answered his own question by reproducing similar findings when extending the study to London postmen and less active postal clerks.

Today, systematic reviews conclude that physical inactivity is a key risk factor for the leading non-communicable diseases and, conversely, that regular physical activity has a fundamental role in the primary and secondary prevention of many diseases and injuries. We have an incontrovertible evidence base for the millennia-old conclusion: *physical activity is medicine.*

Simon Sinek, a successful British-American author and motivational speaker, encourages everybody to 'start with why',[2] and this is relevant if we expect people to undertake physical activity. Epidemiological data provide part of a compelling reason to exercise; the mechanistic 'why'–asking what does exercise do at the cellular/tissue level?–complements the epidemiological data. Why does physical activity confer so many health benefits unmatched by any medication?

Galen believed that physical activity 'thins the body, hardens and strengthens muscles, increases flesh, and elevates blood volume'.[3] Was he wrong? Here we explore Galen's hypothesis by delving into the physiological mechanisms whereby physical activity influences many (perhaps all) tissues and organ systems for health.

## PHYSIOLOGY OF PHYSICAL ACTIVITY: A CLINICIAN'S PRIMER

The following describes the basic physiology of physical activity, one of the most extreme stresses to which the body can be exposed (Fig. 2.1).

### Maintaining homeostasis—a fancy word for survival

Physical activity provokes widespread changes in numerous cells, tissues and organs as a response to, or consequence of, the increased metabolic activity of contracting skeletal muscle. This preserves cellular oxygenation and acid-base homeostasis–both of which are critical for life. The physiological response depends on duration, intensity and frequency of the activity, as well as environmental conditions.

If we take a muscle-centric view, nearly all bodily systems support contracting skeletal muscle. The cardiovascular and respiratory systems instantly increase oxygen availability, release glycogen and fat for energy

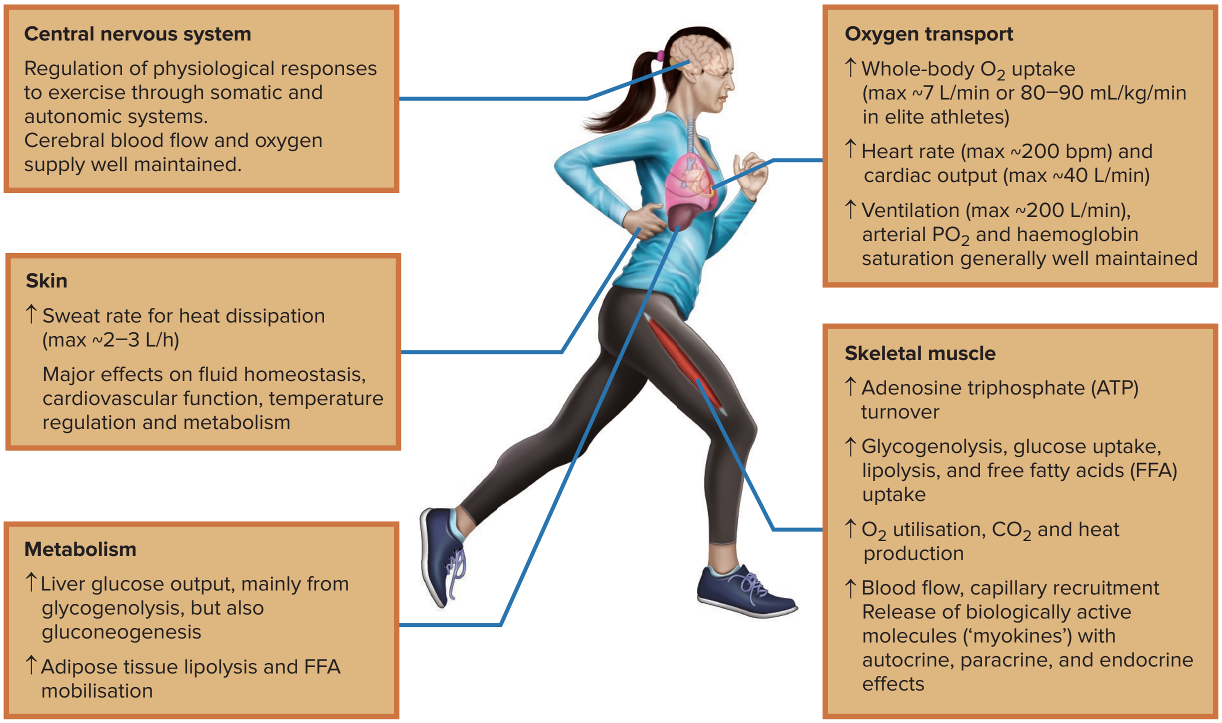


**Figure 2.1** A summary of the physiological response to physical activity

ADAPTED FROM *CELL*, 159, HAWLEY JA, HARGREAVES M, JOYNER MJ ET AL. INTEGRATIVE BIOLOGY OF EXERCISE, 738–49, FIGURE 1, 2014, WITH PERMISSION FROM ELSEVIER[5]

in the muscle and remove metabolic waste products and carbon dioxide. Free fatty acids are released from adipose tissue, and the liver generates glucose. The nervous system is activated as are numerous endocrine signals to help regulate all of these functions. The subsequent forces generated by skeletal muscle contractions and gravity then put stress on bone, ligaments and tendons.[4]

### Adaptive protein changes

Most of physical activity's long-term health benefits result from adaptations in the activity and abundance of proteins involved in specific metabolic, physiological and biomechanical processes–such as mitochondrial respiratory function, calcium cycling and contractile efficiency. These changes are accomplished via shifts in gene transcription and protein translation as well as post-translational modifications.

The energetic and mechanical challenges imposed by physical activity are transient, as are the adaptive cellular responses which occur during the hours following physical activity. Therefore, the adaptive increase in any protein as the result of regular physical activity is a function of:[6]

- the half-life of the protein
- the transient increase in expression that occurs during recovery in between physical activity bouts
- the decrease in expression that occurs between bouts.

That explains why one cannot exercise for 5 minutes and be 'vaccinated' against the ails of physical inactivity for life. Use is or lose it. On the other hand, the good news is that every step counts!

## BENEFITS

Which mechanisms underlie physical activity's force for preventing disease and improving health? Here we outline some of the physiological and mechanistic evidence for physical activity's benefits for different organs and systems (summarised in Table 2.1). We direct you to the relevant chapters for further reading.

### Brain function and mental health

Physical activity epidemiology began with studies that evaluated cardiac function as an outcome, as mentioned previously. Dramatic advances in neuroscience in the 2000s made it clear that physical activity has benefits above the neck as well as below it.

#### Cognitive decline

Physical activity is associated with a reduced risk of cognitive decline and risk of dementia, including Alzheimer's disease. In a meta-analysis of 15 prospective studies of 1–12 years duration with more than 33000 participants, greater amounts



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A

**Table 2.1 Summary of benefits of regular physical activity**

| Health benefit | Strength of evidence |
|---|---|
| Reduced risk of: | |
| • premature death | Strong |
| • cardiovascular disease | Strong |
| • stroke | Strong |
| • high blood pressure | Strong |
| • adverse blood lipid profile | Strong |
| • type 2 diabetes mellitus | Strong |
| • gestational diabetes mellitus | Strong |
| • metabolic syndrome | Strong |
| • bladder, breast, colon, endometrial, oesophageal adenocarcinoma, renal and gastric cancers | Strong |
| • depression | Strong |
| • anxiety | Strong |
| Prevention of weight gain | Strong |
| Weight loss in conjunction with reduced calorie intake | Strong |
| Decreased pain and improved physical function in adults with osteoarthritis of the knee and hip | Strong |
| Prevention of falls | Strong |
| Improved cognitive function in older adults | Strong |
| Improved physical function for older adults with frailty | Strong |
| Improved sleep quality | Strong |
| Lower risk of: | |
| • hip fracture | Moderate |
| • lung cancer | Moderate |
| Increased bone density | Moderate |

ADAPTED FROM PHYSICAL ACTIVITY GUIDELINES ADVISORY COMMITTEE SCIENTIFIC REPORT 2018, DEPARTMENT OF HEALTH AND HUMAN SERVICES USA[14]

of physical activity were associated with a 40% reduced risk of cognitive decline.[7]

One explanation is that regular aerobic physical activity blunts increases in cerebral choline, a metabolite that increases with neural loss, which is characteristic in Alzheimer's dementia and dementia with Lewy bodies.[8] Physical activity promotes brain health via its well-known attenuating influences on atherosclerotic cerebrovascular disease.[9] Neurotrophic factors, such as brain-derived neurotrophic factor (BDNF) and insulin-like growth factor 1 (IGF-1), are also implicated in age-related brain atrophy and neurodegenerative disease (see Chapter 31).

## Anxiety and depression

Physical activity reduces both state and trait anxiety in adults and older adults. Physical activity reduces the risk of experiencing depressive symptoms and frank depression across the lifespan. Performing more than 30 minutes of physical activity per day reduces the odds of experiencing depression by 50%.[10]

One explanation is the 'endorphins hypothesis' that physical activity augments endorphin secretion. These endogenous brain opioid peptides reduce pain and cause general euphoria.[11] Regular aerobic activity is also associated with lower sympathetic nervous system and hypothalamic-pituitary-adrenal axis reactivity, which plays a critical role in developing adaptive responses to physical and psychological stressors (Chapters 21 and 22).[12]

## Sleep

Acute bouts of physical activity and regular physical activity improve sleep. In a meta-analysis of 66 controlled intervention studies involving over 1200 adults, physical activity improved total sleep time, sleep efficiency, sleep onset latency and overall sleep quality.[13] However, the underlying mechanisms are currently being investigated.

## Cancer prevention

Physical activity likely improves quality of life and reduces risk of recurrence in cancer patients. Physical activity is also linked with reduced risks of bladder, breast, colon, endometrial and oesophageal adenocarcinoma, renal and gastric cancers, with risk reductions ranging from 10–20%. Sedentary behaviour increases the risk of endometrial, colon and lung cancers by 20–35%.[14]

Evidence from mouse studies shows that physical activity:[15]

- controls cancer progression through direct effects on tumour intrinsic factors, such as growth rate, metastasis, tumour metabolism and immunogenicity of the tumour (Fig. 2.2)
- regulates tumour growth through interplay with systemic factors

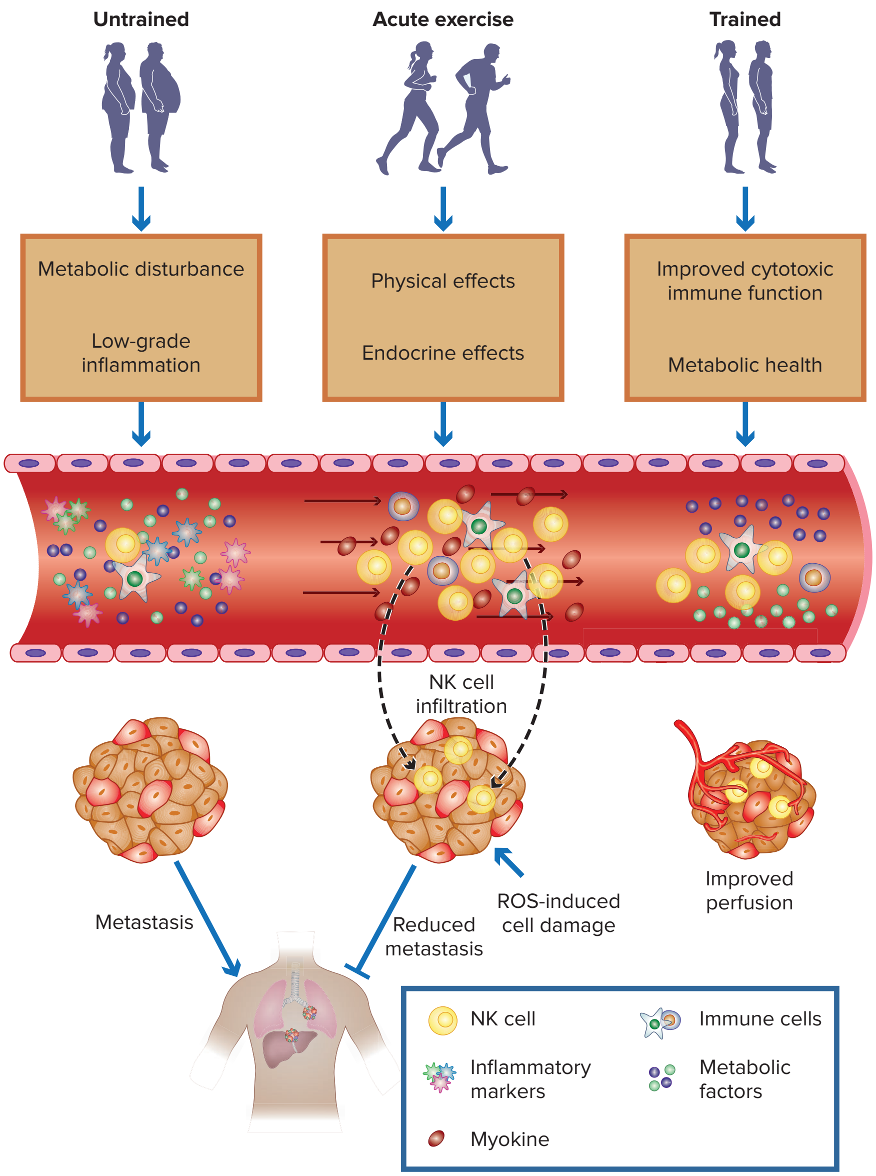


**Figure 2.2** Molecular mechanisms linking physical activity to cancer protection. Physical activity consists of acute sessions leading to physical regulation (increased blood flow, shear stress on the vascular bed, temperature increases, sympathetic activation) and endocrine regulation (release of catecholamines and exercise hormones, myokine secretion) that results in increased tumour perfusion, oxygen delivery, intratumoral metabolic stress, cellular damage and reactive oxygen species (ROS) production. These acute changes are able to elicit signalling pathways that prevent metastasis

- alleviates adverse events related to cancer and its treatment
- improves cancer treatment efficacy.

(Chapter 20.)

## Cardiometabolic health

### Cardiovascular disease

There is very strong evidence of a significant relationship between greater amounts of physical activity and decreased incidence of cardiovascular disease, stroke and heart failure.[14] A meta-analysis of 21 prospective cohort studies with more than 650000 participants found that physical activity is associated with a 10–30% reduced risk of cardiovascular disease.[16]

One important underlying mechanism of action is physical activity's ability to increase vascular nitric oxide (NO) concentration. Nitric oxide is responsible for vasodilation, which lowers peripheral resistance and increases vessel perfusion. Endothelial nitric oxide synthase, the main source of NO, is upregulated by an increase in flow-mediated shear stress associated with physical activity, due to a complex pattern of intracellular regulation like acetylation and phosphorylation.[17] (Chapter 10.)

### Diabetes mellitus

The benefits of physical activity in people with type 1 diabetes include improved insulin sensitivity, improved blood lipid profiles, decreased resting heart rate and blood pressure, decreased body weight and decreased risk of coronary heart disease.[19]

Physical activity reduces the risk of developing type 2 diabetes and provides considerable benefits for people who have type 2 diabetes. Regular aerobic and resistance

## Physical activity or pharmacotherapy—comparative effectiveness

Physical activity prescription is about as effective as drug interventions in terms of its mortality benefits in the secondary prevention of coronary heart disease and diabetes, stroke rehabilitation and heart failure treatment. In the case of stroke rehabilitation, in particular, physical activity is more effective than drug interventions.[18]

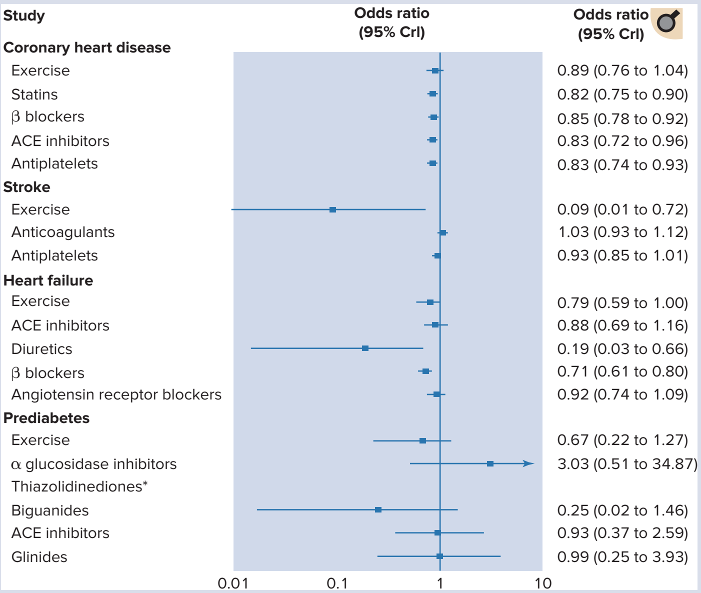


**Figure 2.3** Comparative effectiveness of exercise and drugs. Findings of network meta-analysis: effects of exercise and drug interventions compared with control on mortality outcomes in coronary heart disease, stroke, heart failure and prediabetes. Results shown are odds ratios and 95% credible intervals. Odds ratios lower than 1.00 favour intervention compared with control

ACE=angiotensin converting enzyme

*Number of data points for thiazolidinediones was insufficient to obtain an estimate of odds ratio compared with control

ADAPTED WITH PERMISSION FROM *BR J SPORTS MED.* 2015 NOV; 49(21): 1414-1422.DOI: [10.1136/BJSPORTS-2015-F5577REP] activity can reverse many of the defects in metabolism of both fat and glucose in people with type 2 diabetes and improve their haemoglobin A1c (HbA1c).[20] A systematic review including 20 cohort studies reported an inverse relationship between volume of moderate-to-vigorous physical activity and risk of type 2 diabetes, finding an average risk reduction of over 40% when comparing the most active with the least active participants.[21]

One of the most well-established mechanisms through which people with type 2 diabetes improve metabolic health with physical activity is through adaptations to skeletal muscle. Physical activity enhances muscle membrane glucose transport capacity by recruiting GLUT-4, a critical transport protein, to the sarcolemma and T tubules, where the protein can be active. Increasing the expression of GLUT-4 in skeletal muscle serves to 'mop up' glucose from the bloodstream and move it into muscle, thereby reducing the overall demand for insulin.[22] (Chapter 8.)

### Hypertension

Physical activity reduces blood pressure among adults with prehypertension and normal blood pressure.[14] A narrative review of 27 randomised controlled trials showed that regular medium- to high-intensity aerobic activity reduces blood pressure by a mean of 11/5 mmHg.[23]

The antihypertensive effects of physical activity are mediated through enhanced baroreceptor sensitivity, decreased norepinephrine levels, reduced peripheral vascular resistance, improved insulin sensitivity, and alterations in the expression of vasodilator and vasoconstrictor factors. Aerobic activity decreases left ventricular mass and wall thickness, upregulates central antioxidant concentrations, reduces pro-oxidant levels and arterial stiffness, and increases central nitric oxide synthase activity. All of these adaptations contribute to superior endothelial function.[24] (Chapter 10.)

## Pain reduction

When performed regularly, aerobic activity may be as effective as non-steroidal anti-inflammatory medication for reducing pain.[25, 26]

As in depression, elevated serum beta-endorphin concentrations induced by physical activity promote several psychological and physiological changes, including altered pain perception and responses to numerous stress hormones such as catecholamines and cortisol.[27]

Combining physical activity with other non-pharmacologic therapies such as cognitive behavioural therapy and self-management education may be an effective treatment strategy for pain reduction.[28, 29] (See Chapters 5 and 6, *Clinical Sports Medicine, Volume 1: Injuries*.)

## Musculoskeletal health

### Osteoarthritis

Vigorous physical activity does not accelerate osteoarthritis in normal joints.[30] On the contrary, aerobic and resistance activity reduce pain and improve physical function and quality of life for both osteoarthritis of the knee and hip.[14]

In an osteoarthritic knee, interleukin-1 beta induces the release of prostaglandins and NO, which ultimately results in reduced proteoglycan synthesis and reduced extracellular cartilage matrix. Dynamic compression of chondrocytes counteracts this release of prostaglandins and NO.[31] Thus, dynamic mechanical compression of an osteoarthritic knee through physical activity may inhibit the underlying inflammatory process, thereby reducing pain and permitting superior physical function (Chapter 16).

### Osteoporosis

Physical activity is an important stimulus for the prevention and treatment of osteoporosis. Mechanical loading of physical activity improves bone microarchitecture, increases bone density and bone strength via the process of mechanotransduction (Fig 2.4). It also increases patients' strength and balance which reduces fall risk. During resistance activity (training or activities of daily living) muscle forces applied to bone at points of tendon attachments generate stimuli that promote an osteogenic response (Chapter 17).

## Weight management

Although physical activity is not a primary independent solution to weight loss,[32] it does help attenuate weight gain. Prospective studies demonstrate an inverse association between physical activity and both weight gain and incidence of obesity, and a positive association between

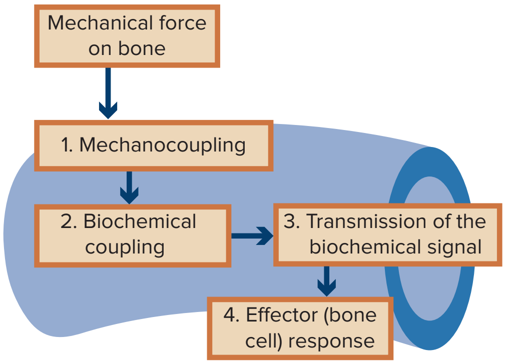


**Figure 2.4** The four elements of mechanotransduction—how physical activity promotes bone health



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physical activity and maintenance of a BMI within the healthy range of 18.5 to 25 $kg/m^2$.[14]

Substantial increases in physical activity can create energy deficits through increased energy expenditure, due to an increase in energy metabolism and requirements. Physical activity's stimulus also provides valuable metabolic adaptations that improve energy and macronutrient balance regulation. At high levels of physical activity, there is tight coupling between energy intake and energy expenditure, suggesting that physical activity also improves appetite control.[33] (Chapter 7.)

## Healthy ageing

Physical activity slows or reverses declines in intrinsic capacity, and can help older adults compensate in ways that maximise their functional ability and independence. Regular aerobic and resistance activity in older adults has been shown to help improve musculoskeletal function and mobility, prevent cognitive impairment, delay the onset of dementia, reduce the risk of falls, and maintain sensory capacity to realise healthy ageing.[34–36]

Musculoskeletal function and mobility can be maintained thanks to physical activity's role in protecting against sarcopenia. After 50 years of age, muscle mass decreases at an annual rate of 1–2%. Muscle strength declines by 1.5% between the ages of 50 and 60 and by 3% thereafter, due to denervation of motor units and a net conversion of fast type II muscle fibres into slow type I fibres (Chapter 31).[37]

## Longevity

Physical activity reduces many major mortality risk factors including hypertension, type 2 diabetes mellitus, coronary heart disease, stroke and cancer. There is a clear inverse dose-response relationship between the amount of moderate-to-vigorous physical activity and all-cause mortality, with risk reduction per unit of time greater for more vigorous activity.[38] All-cause mortality is decreased by up to 35% in physically active people compared to inactive people.[39] Meeting the recommended physical activity guidelines of 30 minutes of moderate-intensity physical activity on 5 days a week compared with doing no activity is associated with a reduction in mortality risk of 19%.[40]

From the opposite perspective, regular physical activity is associated with an increase in life expectancy of up to 7 years.[39] Looking down the microscope, higher levels of physical activity are associated with longer telomeres, which are recognised as the caps at the end of each strand of DNA that protect our chromosomes, akin to the plastic tips at the end of shoelaces. Telomere length of leukocytes and skeletal muscle cells may be positively associated with healthy ageing and inversely correlated with the risk of cancer, cardiovascular disease, obesity, diabetes, chronic pain and stress.[41]

## Social wellbeing

Many psychosocial benefits come from physical activity. Being active has the potential to improve mood, reduce stress, improve self-esteem, improve body image, improve confidence and build positive attitudes and habits (Table 2.1).

Being physically active provides opportunities to meet people and socialise, learn cooperation, foster healthy competition, challenge personal limits and achieve goals. The values and skills learnt on the sporting field can also translate to other areas of life, enabling personal development and wider success in multiple domains.

# RISKS

Physical activity's benefits do not come without some risk, particularly when vigorous activity is undertaken suddenly by untrained or previously sedentary individuals. And although physical activity's health benefits far outweigh its risks, each and every risk must still be considered whenever prescribing to a patient population.[42]

Musculoskeletal injury is the most common risk. More serious but much less common risks include cardiac risks such as sudden cardiac arrest and myocardial infarction. The following is not intended to represent a comprehensive list of physical activity's risks. Rather, it provides a general overview of systems-based considerations and aims to prompt further reading.

## Musculoskeletal risks

As *Clinical Sports Medicine Volume 1: Injuries* explores, injuries from physical activity can affect any type of musculoskeletal connective tissue. Injury to these tissues may be categorised as being either acute or due to overuse, based on the mechanism of injury and rapidity of symptom onset. Musculoskeletal injuries include those such as acute strains and tears, chronic strain, stress fractures, traumatic fractures, cartilage tears, tendinopathies, joint dislocations and bursitis. Although individuals who engage in physical activity have a higher risk of incurring minor injury, people who do not regularly participate in physical activity are more likely to incur more severe injuries when engaging in such activity.[43]

After intense physical activity for an extended period of time, such as in marathon running, skeletal muscle can break down rapidly causing rhabdomyolysis. However, exertional rhabdomyolysis is relatively uncommon, with an incidence of approximately 30 per 100 000 patient years.[44]

## Cardiac risks

Although the most common risk of physical activity is musculoskeletal injury, vigorous physical activity in unaccustomed individuals can also trigger adverse cardiac responses, including acute myocardial infarction, malignant arrhythmias and sudden cardiac death. Importantly, while intense physical activity can influence the occurrence of sudden cardiac death, regular physical activity is associated with an overall reduction in the risk of the event and so may still be appropriately recommended in most patients (Chapters 9 and 10).[45]

## Respiratory risks

Physical activity does not cause asthma; however, it can trigger exercise-induced bronchoconstriction. The underlying pathogenesis is poorly understood, and it is commonly misdiagnosed due to neither sensitive nor specific symptoms such as dyspnoea, chest tightness, wheezing and cough (Chapter 11).[46]

## Dehydration and heat stroke

The incidence of heat stroke has increased in past decades, and it accounts for more deaths than all other natural disasters combined.[47] It is the second highest cause of death in sport after cardiac conditions.[48] Yet, given the number of persons exercising in heat, such cases remain rare, suggesting a natural protection from heat stroke in most athletes.

During prolonged physical activity, particularly in the heat, body water is lost via sweating. The fluid loss decreases circulatory blood volume, blood pressure and sweat production, which is often accompanied by weakness, fatigue, vomiting and diarrhoea.[49]

Physical activity performed in the heat can cause several physiological responses within the body that limit the performance capability of the individual, thereby protecting from exertional heat illness. When the person exercising in the heat is allowed to stop voluntarily, these inbuilt safety mechanisms come to the fore, preventing the development of heat stroke. When heat stroke does occur there are usually associated factors–recent illness, drug use, genetic predisposition–to explain these rare events (Chapter 23).

## REFERENCES

References for this chapter can be found at www.mhhe.com/au/CSM5e

Chapter 3

# Prescribing physical activity: the clinical assessment

with DANIEL FRIEDMAN

*Hippocrates said 'Walking is man's best medicine'–and this may have some personal challenges for you if you're very busy with work, or kids, or both, or you may be in pain or have other priorities . . . but my question for you is: Can you limit your sitting and sleeping to just 23 and 1/2 hours a day?*

Dr Mike Evans, physician, Canada

More than 6 million YouTube viewers around the world are aware of this chapter's opening quote. Canadian physician Dr Mike Evans literally 'went viral' with his whiteboard animation of stories that illustrate the enormous potential of regular physical activity and limiting sedentary behaviour in the primary and secondary prevention of many diseases. However, this potential still remains largely untapped and only partially realised in day-to-day clinical practice. Despite the many calls for adoption of physical activity as a vital sign,[1-3] only a third to half of primary care physicians regularly counsel their patients on physical activity.[4, 5]

Many national action plans on physical activity recommend that clinicians should counsel on physical activity,[6] yet progress to meet targets has been slow and inconsistent.[7] The lack of physical activity training in medical and allied health school curricula, as well as in continuing professional development, means that clinicians often lack experience, knowledge and confidence to counsel their patients on physical activity.[8, 9] Many clinicians meet physical activity counselling outcomes with scepticism and distrust,[10] and instead reach for the familiar default–the prescription pad–even when a medication has limited evidence or a large number needed to treat (NNT), as well as the ever-present risk of adverse events. Failing to counsel on physical activity represents a missed opportunity–one that would enable clinicians to improve the health of patients, and with minimal cost.[11, 12]

Here we summarise the need for regular physical activity counselling in clinical practice. We share a straightforward framework for counselling that can be used easily in a variety of settings. This precedes Chapter 4, where we explore the different principles and elements of exercise prescription.

Establishing the optimum template for physical activity counselling takes time and practice, and can be achieved by considering the following questions in turn:

- Why perform routine physical activity counselling?
- Who should be performing the counselling? And who should be receiving it?
- When and where should counselling be performed?
- What should be included in the counselling?
- Where else can the clinician turn to find counselling resources?
- What should the clinician do if their time with a patient is limited?
- What else can be done to support routine counselling?

## WHY ASSESS AND COUNSEL?

As emphasised in Chapter 1, physical inactivity has reached pandemic proportions. It is a global-scale problem that demands effective, scalable and low-cost solutions. One such solution is physical activity counselling.

### Evidence base and guidelines

Despite mixed evidence regarding effective actions in health systems for increasing physical activity, face-to-face interventions delivered in primary care or community settings have been shown to increase physical activity over 12–24 months.[13] In 2017, the World Health Organization (WHO) identified physical activity counselling and referral as part of routine primary healthcare services as a cost-effective 'best buy' for tackling non-communicable diseases (NCDs),[14] formalising the notion that they can increase self-reported physical activity at a reasonable cost.[15] This best buy is a pillar of the WHO's Global Action Plan on Physical Activity 2018–2030.[7]

Similarly, the UK National Institute for Health and Care Excellence (NICE) recommends that primary care practitioners deliver tailored, brief physical activity advice to patients and follow this up at subsequent appointments. In its recommendation, NICE defines brief advice as verbal advice, discussion, negotiation or encouragement, with or without written or other support or follow-up. Physical activity interventions can vary from basic advice to a more extended, individually focused discussion, often referred to as a brief intervention[16] (see 'Motivational interviewing' in Chapter 5).

### What does the evidence suggest?

The number needed to treat (NNT) with an intervention of physical activity promotion, compared with any control, for one additional sedentary adult to report meeting recommended levels of physical activity at 12 months is 12.[17] Compare this to another brief intervention, such as providing a smoker with tobacco cessation advice, which has an NNT between 50 and 120.[18]

## A clinician's responsibility

Clinicians have a central role and responsibility in enabling all patients to live healthy lives. They should be well poised to promote comprehensive lifestyle interventions for the prevention and management of chronic diseases, and to provide the necessary guidance and support for patients to change their unhealthy behaviours. In a survey of 7238 people in Sweden, 76% of respondents thought healthcare professionals have a responsibility to promote physical activity to their patients.[19] However, this responsibility for patients' physical activity levels should be shared with other healthcare professionals, patients and society as a whole.[10]

Given that the clinician's voice is widely trusted and has considerable influence on public and individual opinion, routine patient encounters in all settings offer frequent and meaningful opportunities for supporting behaviour change. Clinicians have the potential to reach a large proportion of the population regularly and are therefore well placed to promote physical activity, especially to the least active, at-risk individuals. In developed countries, for example, 70–80% of adults visit their general practitioner at least once a year.[20]

## A primary and secondary prevention opportunity

Frequent patient encounters offer many opportunities for primary and secondary prevention, such as advising on smoking cessation, diet and nutrition, stress management and other lifestyle interventions. Provision of effective advice on physical activity is less common, yet given physical activity's contributions to health, clinicians should regularly implement evidence-based interventions that solely target physical activity, as well as those delivered in combination with other risk factors such as diet, smoking and alcohol.

This shift of focus to prevention activities will reduce the incidence of chronic diseases and ultimately lessen physical inactivity's current health and economic burden, as discussed in Chapter 1.

### WHO SHOULD DO IT?

*Physical activity counselling should not be limited to sport and exercise medicine physicians.* All clinicians should be trained in performing basic assessment and providing brief advice. This particularly applies to allied health professionals, who often have more time with patients than do primary care physicians.

Further, do not neglect the role clinic staff can play in assisting with assessment, which may be performed in the waiting room prior to consultation.

### WHO SHOULD RECEIVE IT?

*Physical activity counselling is beneficial for everyone.* All individuals, of all ages and abilities, should be encouraged to be active and gradually increase their activity levels to experience the health benefits. At-risk, sedentary individuals with chronic diseases in particular should be advised to view physical activity as medicine, alongside other aforementioned lifestyle interventions.

### WHEN AND WHERE TO DO IT?

Physical activity counselling should ideally be performed during every clinical encounter, and should be routinely assessed as a vital sign alongside blood pressure and heart rate.[21, 22] All forms of counselling should be tailored to meet the needs and ability of the patient, as well as the time constraints of the consultation.

It can be useful conceptually to separate physical activity counselling opportunities into three separate occasions:

- upon first meeting a patient, when taking a complete medical history
- during every following clinical encounter, in brief, alongside other lifestyle counselling such as diet (Chapter 6)



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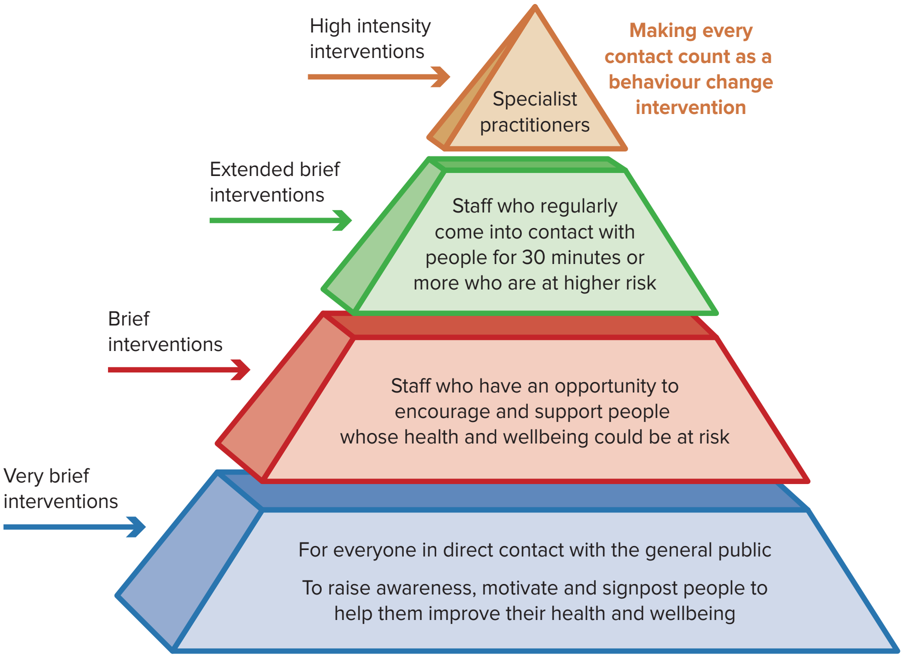


**Figure 3.1** Behaviour change interventions mapped to NICE Behaviour change: individual approaches


- during separate follow-up consultations booked solely for physical activity counselling, offering more time for extensive discussion and detailed prescription.

The NICE categorises these opportunities into more concrete terms, as illustrated in Fig. 3.1.

However, counselling should not only take place in the clinician's rooms. Some of the assessment may be performed prior to the consultation, for example in the waiting room beforehand through patient questionnaires. Each clinic should identify a method that is both feasible and efficient amid busy schedules.

## WHAT SHOULD BE INCLUDED IN COUNSELLING?

The common elements of counselling are shown in Fig. 3.2 and are expanded in the section below ('The 5As model of behaviour change').

## WHERE ELSE CAN THE CLINICIAN TURN FOR COUNSELLING RESOURCES?

A number of health departments, medical colleges and independent organisations offer their clinicians how-to guides or manuals for physical activity counselling (Table 3.1). There are diverse resources available, differing in length, level of detail and supplementary tools used.

Despite the number of apparently different manuals, they are based on the same fundamental principles and have been adapted from a common template or structure: the 5As model of behaviour change.

## THE 5As MODEL OF BEHAVIOUR CHANGE

The 5As model of behaviour change is a stepwise, evidence-based approach to physical activity counselling that is used worldwide in a range of healthcare settings

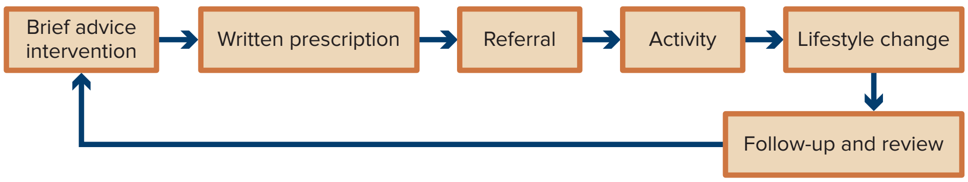


**Figure 3.2** A common clinical pathway for physical activity counselling

**Table 3.1** **Physical activity counselling manuals for clinicians around the world**

| Country | Source | Resource |
|---|---|---|
| Australia | Royal Australian College of General Practitioners (RACGP) | Guidelines for preventive activities in general practice (Red Book) |
| Canada | Alberta Centre for Active Living | Physical Activity Counselling Toolkit |
| South Africa | The Chronic Disease Initiative for Africa (CDIA)—iChange4Health | Helping People Change |
| Sweden | Swedish Professional Associations for Physical Activity (YFA) | Physical Activity in the Prevention and Treatment of Disease (FYSS) |
| Switzerland | Swiss College of Primary Care Medicine (and others) | Physical Activity Promotion in Primary Care (PAPRICA)—Handbook for Doctors |
| UK | NHS Health Scotland | Physical Activity Pathway Practitioners Guide |
| USA | American College of Sports Medicine (ACSM) | Guidelines for Exercise Testing and Prescription |

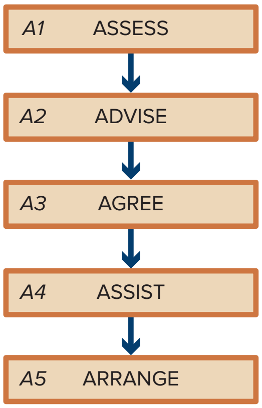


**Figure 3.3** The 5As model of behaviour change

(Fig. 3.3).[22, 23] The model, originally developed for counselling in tobacco cessation,[24] has been adapted for other lifestyle interventions to much success.

The 5As have a strong foundation in behaviour change theory and they are practical for busy patient-care settings. The approach is supported by evidence for increases in healthy behaviours, positive influence on mediators of behaviour change, and increased healthcare provider communication skills about behaviour change.[25]

We explore each of the key actions of the 5As that the clinician may follow to support patients to initiate behaviour change and sustain it. It is not intended to represent the only way to counsel, but rather aims to provide a tasting plate of different counselling components.

## A1: Assess

*Assess the patient's current physical activity level and readiness for physical activity.*

A patient's physical activity and sedentary behaviour levels should be assessed on initial consultation, and at every subsequent clinical contact.

Clinicians may perform the assessment in person during the consultation, or it may be completed by the patient independently prior to the appointment to save time (for example, by completing a questionnaire while in the waiting room).

In general, it is important to assess:

- current levels of **physical activity** in all domains (recreation, transport, work, school etc.), including:
  - *type*–aerobic, strength, flexibility or balance
  - *frequency*–How often? How many days per week?
  - *intensity*–How hard are you working during the activity? During activity is it difficult to breathe or speak?
  - *duration*–For how long? At least 10 minutes at a time?
- current levels of **sedentary behaviour** (sitting or lying down) in all domains
- risks and contraindications.

There are many different questionnaires for physical activity assessment. The Canadian Society for Exercise Physiology (CSEP) 'Get Active Questionnaire',[26] which will be familiar to some readers as the PAR-Q, was designed to allow patients to independently pre-assess their readiness for physical activity, and decide whether it is necessary for them to seek advice from a clinician before becoming more physically active.

If the advice of a clinician is required, the patient should be assessed through a medical history and physical examination that specifically focus on contraindications to physical activity. (See 'Screening', in Chapter 46 of *Clinical Sports Medicine Volume 1: Injuries*.) Risk stratification