【Special Article】

The Japanese version of the Toronto Charter for Physical Activity: A Global Call for Action

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Abstract

"The Toronto Charter for Physical Activity: A Global Call for Action" was adopted at the Third International Congress of Physical Activity and Public Health held in Toronto, Canada, in May, 2010. The Charter was developed by the Global Advocacy Council for Physical Activity of the International Society of Physical Activity and Health. The authors translated the Charter into Japanese. In this article, we explained the background, process of translation, and contents of the Charter. The Japanese version was attached as appendix.

The Charter is a consensus of researchers, practitioners and policymakers involved in physical activity promotion, and calls for the need for increased priority given to physical activity worldwide. It is an advocacy tool, discussing the rationale, nine guiding principles, and four key areas of action for promoting physical activity. We expect the Charter to be used in various ways such as a checklist for existing and future policies and projects, official document to be shared with policymakers, material that helps researchers to identify research directions, and reference for journal articles.

Key words: Toronto Charter, physical activity, exercise, advocacy, health promotion

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資料1

身体活動のトロント憲章日本語版：世界規模での行動の呼びかけ

The Toronto Charter for Physical Activity: A Global Call for Action

Physical activity promotes wellbeing, physical and mental health, prevents disease, improves social connectedness and quality of life, provides economic benefits and contributes to environmental sustainability. Communities that support health enhancing physical activity, in a variety of accessible and affordable ways, across different settings and throughout life, can achieve many of these benefits. The Toronto Charter for Physical Activity outlines four actions based upon nine guiding principles and is a call for all countries, regions and communities to strive for greater political and social commitment to support health enhancing physical activity for all.

Why a Charter on physical activity?

The Toronto Charter for Physical Activity is a call for action and an advocacy tool to create sustainable opportunities for physically active lifestyles for all. Organisations and individuals interested in promoting physical activity can use this Charter to influence and unite decision makers, at national, regional and local levels, to achieve a shared goal. These organisations include health, transport, environment, sport and recreation, education, urban design and planning as well as government, civil society and the private sector.

Physical activity – a powerful investment in people, health, the economy and sustainability

Throughout the world, technology, urbanisation, increasingly sedentary work environments and automobile-focused community design have engineered much physical activity out of daily life. Busy lifestyles, competing priorities, changing family structures and lack of social connectedness may also be contributing to inactivity. Opportunities for physical activity continue to decline while the prevalence of sedentary lifestyles is increasing in most countries, resulting in major negative health, social and economic consequences.

For health, physical inactivity is the fourth leading cause of chronic disease mortality such as heart disease, stroke, diabetes, cancers; contributing to over three million preventable deaths annually worldwide. Physical inactivity also contributes to the increasing level of childhood and adult obesity. Physical activity can benefit people of all ages. It leads to healthy growth and social development in children and reduces risk of chronic disease and improved mental health in adults. It is never too late to start physical activity. For older adults the benefits include functional independence, less risk of falls and fractures and protection from age related diseases.

身体活動のトロント憲章
ー世界規模での行動の呼びかけー

身体活動は、人々の幸福、身体的・精神的健康の増進、疾病予防に役立ち、社会のつながりを深め、生活の質を改善し、さらには、経済的利益をもたらし、環境の保全にも役立つ。健康増進のための身体活動を、実行可能な方法で、様々な場面において、生涯を通じて支援することによって、地域はこれらの多くの恩恵を受けることができる。

身体活動のトロント憲章では、9つの指針に基づく4つの行動（対策）が示されている。本憲章は、すべての国や地域が、あらゆる人々の身体活動を支援する政治的、社会的な取り組みを強めるように求めるものである。

なぜ、身体活動に関する憲章か?

身体活動のトロント憲章は、「行動の呼びかけ」であると同時に、全ての人々が活動的なライフスタイルをおくることができる機会を作り出すための「支援ツール」である。身体活動の推進を行う組織や個人は、共通の目標達成のために、国や地域の政策決定者に影響を与え、彼らの結びつきを強めるためにこの憲章を利用することができる。このような組織には、健康、交通、環境、スポーツ・レクリエーション、教育、都市計画・都市設計ならびに政府、市民団体、民間部門も含まれる。

身体活動ー人々、健康、経済、持続可能性への強力な投資

世界中で起こっている、技術革新、都市化、デスクワーク中心の職場環境の増加、車社会を想定した都市計画は、人々の日常生活から身体活動を奪っている。多忙なライフスタイル、競争社会、家族構成の変化、社会的つながりの希薄化も、不活動を助長していると考えられる。ほとんどの国において、身体活動の機会が減少し続ける一方で、座位中心のライフスタイルを送る者の割合が増え続けており、その結果、健康面、社会面、経済面で好ましくない変化が起こっている。

健康に関しては、身体不活動は、心疾患、脳卒中、糖尿病、がんなどの慢性疾患による死亡原因の第4位となっており、不活動のために世界中で毎年300万人以上の予防できるはずの命が奪われている。身体不活動は、子どもおよび成人の肥満増加の原因にもなっている。身体活動はあらゆる年齢層の人々にとって有益である。子どもにとっては身体的および社会的発達に役立ち、成人では、慢性疾患のリスク軽減と精神的健康の増進につながる。身体活動を始めるのに遅すぎるということはない。高齢者が享受する恩恵としては、機能的自立、転倒・骨折リスクの低減、加齢に伴う疾病の予防などがある。

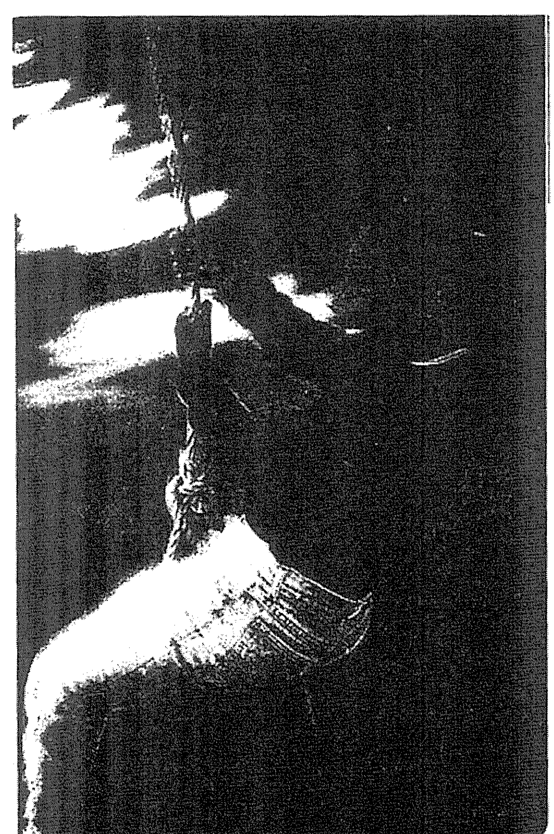
For sustainable development, promoting active modes of travel such as walking, cycling and public transport can reduce harmful air pollution and greenhouse gas emissions, which are also known to negatively impact health. Urban planning, design and redevelopment that aim to reduce dependence on motor vehicles can also contribute to increased physical activity, particularly in those developing countries experiencing rapid urbanisation and growth. Increasing investment in active travel provides more equitable mobility options.

For the economy, physical inactivity contributes substantially to direct and indirect health care costs and has a significant impact on productivity and healthy life-years. Policies and actions that increase participation in physical activity are a powerful investment in preventing chronic diseases and improving health, social connectedness and quality of life as well as providing benefits for economic and sustainable development of countries throughout the world.

Guiding principles for a population based approach to physical activity

Countries and organisations working towards increasing participation in physical activity are encouraged to adopt the following guiding principles. These principles are consistent with the Non Communicable Disease Action Plan (2008) and the Global Strategy on Diet, Physical Activity and Health (2004) of the World Health Organisation as well as other international health promotion charters. To increase physical activity and decrease sedentary behaviour, countries and organisations are encouraged to:

1. Adopt evidence based strategies that target the whole population as well as specific population sub groups, particularly those facing the greatest barriers;
2. Embrace an equity approach aimed at reducing social and heath inequalities and disparities of access to physical activity;
3. Address the environmental, social and individual determinants of physical inactivity;
4. Implement sustainable actions in partnership at national, regional and local levels and across multiple sectors to achieve greatest impact;
5. Build capacity and support training in research, practice, policy, evaluation and surveillance;
6. Use a life-course approach by addressing the needs of children, families, adults and older adults;
7. Advocate to decision makers and the general community for an increase in political commitment to and resources for physical activity;
8. Ensure cultural sensitivity and adapt strategies to accommodate varying 'local realities', contexts and resources;
9. Facilitate healthy personal choices by making the physically active choice the easy choice.



持続的発展が可能な社会の実現に関しては、歩行、自転車、公共交通などの活動的な移動手段を推進することで、健康にも悪影響を及ぼす大気汚染や温室効果ガスの排出を削減することができる。車に依存しない生活を目指した都市計画・都市設計、再開発は、身体活動の推進に役立つ。特に、急速な都市化および成長が進行中の開発途上国においてはなおさら重要である。活動的な移動手段への投資を増やすことで、より公平な（交通弱者にとっても）移動手段の選択肢を提供することができる。

経済に関しては、身体不活動が直接的、間接的な医療費増大の大きな原因となっており、生産性や健康寿命に重大な影響を与えている。身体活動の推進を促す政策や対策は、慢性疾患の予防、健康増進、社会のつながり、生活の質の改善のみならず、世界中の国において経済発展、持続可能な社会発展をもたらす強力な投資となる。

全ての人々を対象とした身体活動推進の指針（9つの指針）

身体活動の推進に取り組もうとしている国および組織では、以下の指針を用いることが推奨される。これらの指針は、WHOの「Non Communicable Disease Action Plan (2008)」・「Global Strategy on Diet, Physical Activity and Health of World Health Organization (2004)」ならびにその他の国際的な健康増進に関する憲章とも内容が一致している。身体活動を推進し、座位行動（座っている時間）を減少させるために、各国および関連する組織には以下を推奨する。

1. 全人口および特定の集団（女性、高齢者、子ども、障がい者、勤労者など）、特に身体動を行うことに大きな障壁を有する人々に対して、科学的根拠に基づいた戦略を用いる。
2. 社会的不平等、健康の不平等、身体活動機会の不均等を減少させるような平等の戦略を用いる。
3. 身体不活動の環境的、社会的、個人的な規定要因の改善に取り組む。
4. 効果を最大にするために、持続可能な対策を、国や地域の各レベルで複数部門の連携を通じて実施する。
5. 研究、実践、政策、評価、調査のための能力を高め（キャパシティ・ビルディング）、トレーニングを支援する。
6. 子ども、家族、成人、高齢者のニーズに対応した、生涯を通じたアプローチを行う。
7. 身体活動に関する政治的取り組みを強化し、資源を増大するように、政策決定者や社会一般に対して政策提言・支援活動（アドボカシー）を行う。
8. 文化的差異に配慮し、多様な地域の現状、背景、資源に応じた戦略を採用する。
9. 身体活動を行うという選択が容易にできるようにすることで、個人が健康な選択をすることを促進する。

A framework for action

This Charter calls for concerted action across four key areas. This action should involve governments, civil society, academic institutions, professional associations, the private sector, and other organisations within and outside the health sector, as well as communities themselves. These four action areas are distinct, yet complementary, building blocks for successful population change.

1. IMPLEMENT A NATIONAL POLICY AND ACTION PLAN

A national policy and action plan provides direction, support and coordination of the many sectors involved. It also assists in focusing resources as well as providing accountability. A national policy and action plan is a significant indicator of political commitment. However, the absence of a national policy should not delay the efforts of state, provincial or municipal organisations to enhance physical activity in their jurisdictions. Policy and action plans should:

- Gain input from a broad constituency of relevant stakeholders;
- Identify clear leadership for physical activity, which may come from any government sector, other relevant non government agencies or from a cross sector collaboration;
- Describe the roles and actions that government, not-for-profit, volunteer and private sector organisations at national, regional and local levels should take to implement the plan and promote physical activity;
- Provide an implementation plan that defines accountability, timelines and funding;
- Include combinations of different strategies to influence individual, social, cultural and built environment factors that will inform, motivate and support individuals and communities to be active, in ways that are safe and enjoyable;
- Adopt evidence based guidelines on physical activity and health.

2. INTRODUCE POLICIES THAT SUPPORT PHYSICAL ACTIVITY

A supportive policy framework and regulatory environment are required to achieve sustainable changes in government and society. Policies that support health enhancing physical activity are needed at national, regional and local levels. Examples of supportive policy and regulations include:

- Clear national policy with objectives for increasing physical activity that state by how much and by when. All sectors can share common goal(s) and identify their contribution;
- Urban and rural planning policies and design guidelines that support walking, cycling, public transport, sport and recreation with a particular focus on equitable access and safety;
- Fiscal policies such as subsidies, incentives and tax deductions that may support participation in physical activity or taxation to reduce obstacles. For example, tax incentives on physical activity equipment or club membership;
- Workplace policies that support infrastructure and programs for physical activity and promote active transport to and from work;

行動の枠組み

この憲章は、以下の4領域にわたって連携した行動（対策）を取るように求める。行動に関わるのは、政府・自治体、市民団体、研究機関、専門家組織、民間団体、その他の健康に関係した、あるいは健康とは直接には関係しない組織である。また、地域社会（コミュニティ）自らが関わるべきである。以下の4つの行動は、明確に区別されるが、補完的に機能して、全ての人々の身体活動推進のための構成要素として働く。

1. 国家政策、行動計画の策定と実行

国家政策と行動計画を策定することにより、関連する部門に対して進むべき方向性が提示され、支援が提供され、相互の協調が促される。また、資源の効果的な利用を助け、責任の所在が明確になる。国家政策と行動計画が策定されていることは、政治的取り組みの程度を示す重要な指標である。しかしながら、国家政策がないことで、地方自治体レベルにおける身体活動推進の取り組みが遅れてはならない。政策や行動計画は以下のようなものでなくてはならない。

- 広い範囲の関係者（ステークホルダー）の意見を取り入れている。
- 身体活動の推進について誰がリーダーシップをとるのかを明確にしている。それは、政府・地方自治体かもしれないし、関連する非政府組織、あるいは複数の組織の協力かもしれない。
- 国、地域のレベルにおいて、政府、非営利組織、ボランティア、民間団体が、どのような役割を担い、計画を実行するのかを示している。
- 責任の所在、スケジュール、資金源を明確にした実施計画を示している。
- さまざまな戦略を組み合わせている。さまざまな戦略とは、個人的、社会的、文化的、物理的環境要因に影響を及ぼすもので、安全でかつ楽しめるやり方によって、個人と地域に対して、情報提供、動機づけ、行動変容支援を行うものである。
- 科学的根拠に基づいた「身体活動と健康」のガイドラインを採用している。

2. 身体活動を支援する施策の導入

政府や社会において持続可能な変化を達成するためには、施策の枠組みと規制が必要である。身体活動を支援する施策は、国および地域レベルで必要である。施策と規制の例を以下に示す:

- 身体活動を「どのくらい」、「いつまでに」増加させるかという目標を伴った明確な国家施策。全部門が目標を共有し、自らの役割を明確にする。
- 歩行、自転車、公共交通の利用、スポーツ・レクリエーションを支援する都市計画・都市設計の方針および指針。これらは特に公平なアクセスと安全性に配慮する必要がある。
- 身体活動の参加を推進するための補助金、インセンティブ、課税軽減といった財政政策。たとえば、身体活動施設やクラブ会員資格に関する税制上の優遇措置。
- 身体活動推進のためのインフラおよびプログラムを支援し、活動的な通勤を推進する職場政策。

- Education policies that support high quality compulsory physical education, active travel to school, physical activity during the school day and healthy school environments;
- Sport and recreation policy and funding systems that prioritise increased community participation by all members of the community;
- Advocacy to engage the media to promote increased political commitment to physical activity. For example, 'Report Cards' or civil society reports on the implementation of physical activity action to increase accountability;
- Mass communication and social marketing campaigns to increase community and stakeholder support for physical activity action.

3. REORIENT SERVICES AND FUNDING TO PRIORITISE PHYSICAL ACTIVITY

In most countries, successful action to promote physical activity will require a reorientation of priorities in favour of health enhancing physical activity. Reorienting services and funding systems can deliver multiple benefits including better health, cleaner air, reduced traffic congestion, cost saving and greater social connectedness. Examples of actions underway in many countries include:

In education:
- Education systems that prioritise high-quality compulsory physical education curriculum with an emphasis on non competitive sports in schools and enhancing physical education training for all teachers;
- Physical activity programs that focus on a range of activities that maximise participation regardless of skill level and that focus on enjoyment;
- Opportunity for students to be active during class, in breaks, at lunch time and after school.

In transportation and planning:
- Transport policies and services, that prioritise and fund, walking, cycling and public transit infrastructure;
- Building codes that encourage or support physical activity;
- Trails in national parks and preserved areas to increase access.

- 質の高い体育授業の必修化、活動的な通学、学校内の身体活動、健康的な学校環境を支援する教育政策。
- 地域住民全員が参加できることに重点を置いたスポーツ・レクリエーション政策と財源システム。
- 身体活動への政治的関与（コミットメント）を促進させるようにマスコミに働きかけること。例えば、説明責任を増すための、身体活動推進対策の実施状況に関する評価表や市民団体による報告書。
- 地域や関係者の身体活動支援を促すマスメディアおよびソーシャルマーケティングキャンペーン。

3. 身体活動に重点を置いたサービスと財源の新たな方向づけ

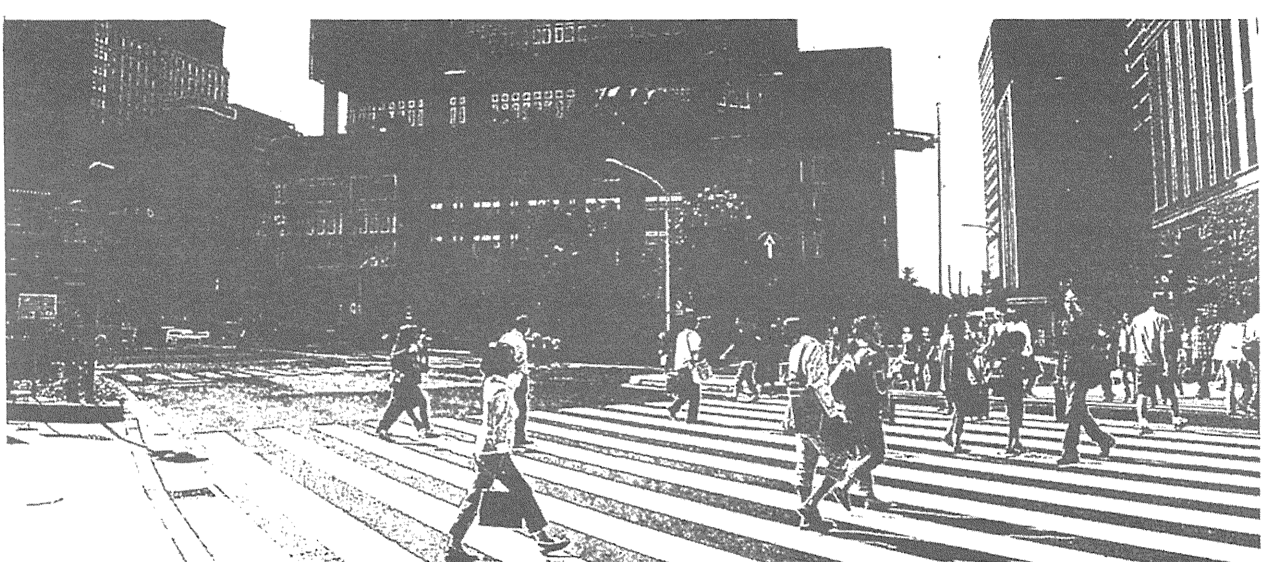
多くの国で、身体活動を推進するための対策を成功させるには、健康増進のための身体活動を支援するような優先順位の再設定が必要である。サービスや財源システムの方向づけを変えることにより、健康増進、きれいな空気、交通渋滞緩和、コスト削減、社会的つながりの強化などのいくつもの恩恵がもたらされる。多くの国で進行中の対策の例として、以下のようなものがある：

教育：

- o 非競争スポーツを重視した質の高い必修体育や、すべての教師に対して体育授業のトレーニングを行うことに重点を置いた教育システム
- o 技能のレベルに関係なく皆が参加できる、楽しさに焦点を当てた幅広い身体活動のプログラム
- o 授業中、休み時間、昼休み、放課後に生徒が活動的になるための機会

交通計画：

- o 歩行、自転車、公共交通のインフラに優先的に財源を投入する交通施策とサービス
- o 身体活動を奨励し、支援する建築基準
- o 国立公園や保護地区の利用を促進する遊歩道・自転車道の設置



In planning and environment:

- Evidence based urban design that support walking, cycling and recreational physical activity;
- Urban design that provides opportunities for sport, recreation and physical activity by increasing access to public space where people of all ages and abilities can be physically active in urban and rural settings.

In workplace:

- Workplace programs that encourage and support employees and their families to lead active lifestyles;
- Facilities that encourage participation in physical activity;
- Incentives for active commuting to work or by public transport rather than by car.

In sport, parks and recreation:

- Mass participation and sports for all, including those least likely to participate;
- Infrastructure for recreational activities across the life-course;
- Opportunities for individuals with disabilities to be physically active;
- Building capacity among those who deliver sport through increased training on physical activity.

In health:

- Greater priority and resourcing of prevention and health promotion including physical activity;
- Screening of patients/clients for levels of physical activity at every primary care consultation, and provision of brief, structured counselling and referral to community programs for insufficiently active patients;
- For patients with diseases/conditions such as diabetes, cardiovascular disease, some cancers or arthritis, screening by health and exercise professionals for contraindications and advice on physical activity as part of treatment, management and review plans.

4. DEVELOP PARTNERSHIPS FOR ACTION

Actions aimed at increasing population-wide participation in physical activity should be planned and implemented through partnerships and collaborations involving different sectors, and communities themselves, at national, regional and local levels. Successful partnerships are developed by identifying common values and program activities and by sharing responsibilities, accountabilities and information. Examples of partnerships that support the promotion of physical activity are:

- Cross-government working groups at all relevant levels to implement action plans;
- Community initiatives involving different government departments and non government agencies (for example: transport, urban planning, arts, conservation, economic development, environmental development, education, sport and recreation, and health) working in collaboration and sharing resources;
- Coalitions of non government organisations formed to advocate to governments for the promotion of physical activity;
- National, regional or local partnership forums with key agencies from multiple sectors, and public and private stakeholders to promote programs and policies;
- Partnerships with population sub groups including indigenous peoples, migrants and socially disadvantaged groups.

都市計画と環境：
- o 科学的根拠に基づく歩行、自転車、余暇身体活動を支援する都市設計
- o あらゆる人（年齢や障がいの有無にかかわらず）が身体活動できる場所へのアクセスを高め、スポーツ、レクリエーション、身体活動の機会を提供するような都市設計

職場：
- o 従業員やその家族が活動的なライフスタイルを送ることを奨励、支援する職場プログラム
- o 身体活動への参加を推進する施設
- o 活動的な通勤、または車ではなく公共交通による通勤のためのインセンティブ

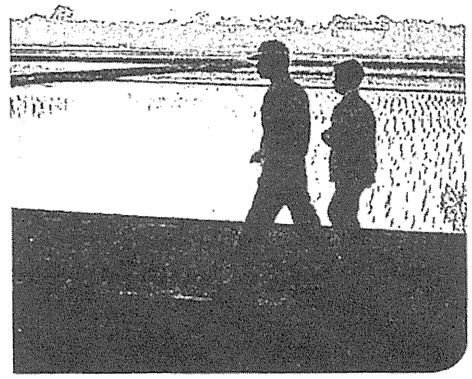
スポーツ、公園、レクリエーション：
- o 参加しそうもない人々を含めて、多くの人が参加するみんなのためのスポーツ
- o 幅広い年齢層が使えるレクリエーションのためのインフラ
- o 障がい者が活動的になれる機会
- o スポーツ指導者に対して、身体活動に関するトレーニングを行い、能力を高めること

健康：
- o 疾病予防と健康増進（身体活動を含む）の優先順位を高め、資源を整備すること
- o プライマリケアにおける患者を対象に身体活動レベルのスクリーニングを実施し、身体活動が不足している患者に対して簡便で構造化されたカウンセリングを提供したり、地域プログラムを紹介したりすること
- o 糖尿病、循環器疾患、一部のがん、関節炎などの疾病を有する患者について、医療従事者および運動指導者による身体活動禁忌（適否）のスクリーニング、疾病治療・管理の一部として実施する身体活動に関する助言を行うこと

4. 対策のためのパートナーシップの構築

国民全体の身体活動推進を目的とした対策は、国と地域レベルで、様々な部門と地域社会を取りこんだ形で、またパートナーシップと協力関係を構築する形で、計画され実行されるべきである。良好なパートナーシップは、共通の価値観とプログラム活動を見出し、果たすべき役割、責任および情報を共有することによって構築される。身体活動推進を支援するパートナーシップの例は以下のとおりである。

- 行動計画の実行を目的としたすべてのレベルにおける政府内ワーキンググループ
- さまざまな政府部門と非政府機関（たとえば、交通、都市計画、芸術、保全、経済開発、環境開発、教育、スポーツ・レクリエーション、健康）が協力し、資源を共有する地域での取り組み
- 身体活動促進を政府・自治体に呼びかけるために結成された非政府組織（NGO）の連携
- プログラムや政策を推進するための、多分野の公共・民間の主要機関の関係者による全国、地方レベルでの情報交換の場
- 先住民、移民、社会的弱者などの特定集団との連携



A call to action

A strong body of science supports the benefits of physical activity for health, the economy and the environment. To achieve a greater commitment to increasing physical activity around the world there is an urgent need for clear direction and strong advocacy. The ***Toronto Charter for Physical Activity*** outlines four actions based upon nine guiding principles. Implementation of the Toronto Charter will provide a solid foundation and direction for health enhancing physical activity in all countries.

We encourage all interested stakeholders to support the adoption and implementation of the ***Toronto Charter for Physical Activity*** and to engage in one or more of the following actions:

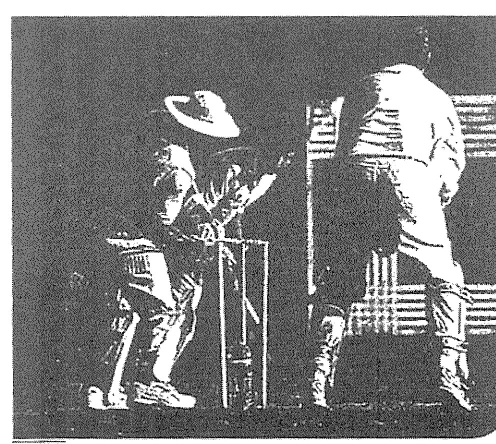
1. Show your agreement with the four areas for action and nine guiding principles by registering your support of the ***Toronto Charter for Physical Activity;***
2. Send a copy of the ***Toronto Charter for Physical Activity*** to at least five of your colleagues and encourage them to do the same;
3. Meet with decision makers in different sectors to discuss how national plans and policy action following the guiding principles of the ***Toronto Charter for Physical Activity*** might positively influence action across sectors;
4. Mobilise networks and partnerships all sectors to support and implement the Toronto Charter.

In turn, members of the Global Advocacy Council for Physical Activity commit to the following actions:

- Translate the final version of the ***Toronto Charter for Physical Activity*** into French, Spanish and possibly other languages;
- Disseminate the final version of the ***Toronto Charter for Physical Activity*** widely;
- Work with physical activity networks and other stakeholder organisations to further mobilise governments and decision makers throughout the world to increase commitment towards the promotion of health enhancing physical activity;
- Continue to partner with other groups and organisations in order to advocate for health enhancing physical activity throughout the world.

For links to supporting resources and to directly forward the Toronto Charter for Physical Activity to colleagues please visit: www.globalpa.org.uk

Global Advocacy Council for Physical Activity,
International Society for Physical Activity and Health.
The *Toronto Charter for Physical Activity: A Global Call to Action.*
www.globalpa.org.uk.
May 20, 2010.



行動の呼びかけ

身体活動の健康、経済、環境に対する恩恵は、強い科学的根拠に裏づけられている。世界中で身体活動推進のための取り組みを拡大するために、明確な方向づけと力強い呼びかけ（アドボカシー）が急務である。**身体活動のトロント憲章**は、9つの指針（guiding principle）に基づく4つの行動（対策）の概要を示している。トロント憲章を実行することで、あらゆる国における健康増進のための身体活動についての確固とした基盤と方向性を得ることができる。

興味・関心のある全ての関係者は、**身体活動のトロント憲章**の採用と実行を後押しし、以下の行動の中から一つ以上の**行動**を行っていただきたい。

1. **身体活動のトロント憲章**への支持を表明し、4つの行動と9つの指針に同意を示す。
2. **身体活動のトロント憲章**のコピーを少なくとも5人の同僚に送付し、同様に支持してもらうよう依頼する。
3. 様々な部門の政策決定者と会い、**身体活動のトロント憲章**の原則に基づく国家計画や政策活動が、諸部門の活動に好影響を与えることを伝える。
4. トロント憲章を支持し、実行するために、あらゆる部門のネットワークとパートナーシップを活用する。

「Global Advocacy Council for Physical Activity（注）」のメンバーは以下の**行動**に取り組んでいる。

- **身体活動のトロント憲章**をフランス語、スペイン語のほか、可能な限り他の言語に翻訳する。
- **身体活動のトロント憲章**を広く普及する。
- 身体活動推進ネットワークおよびその他の関係者組織と協働して、健康増進のための身体活動を推進するための取り組みの強化に向けて、世界中の政府と政策決定者に働きかける。
- 世界中で健康増進のための身体活動を支援するために、他の団体や組織との連携を継続する。

（注）Global Advocacy Council for Physical ActivityはInternational Society of Physical Activity and Healthに設置された協議会の一つです。

身体活動のトロント憲章および関連する情報源へのリンクは
www.globalpa.org.uk
を参照して下さい。

引用: Global Advocacy Council for Physical Activity, International Society for Physical Activity and Health. The Toronto Charter for Physical Activity: A Global Call to Action. www.globalpa.org.uk. May 20 2010.

ISPAH International Society for Physical Activity and Health

GAPA GLOBAL ADVOCACY FOR PHYSICAL ACTIVITY Advocacy Council of ISPAH

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Two risk score models for predicting incident Type 2 diabetes in Japan

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Abstract

Aims Risk scoring methods are effective for identifying persons at high risk of Type 2 diabetes mellitus, but such approaches have not yet been established in Japan.

Methods A total of 1935 subjects of a derivation cohort were followed up for 14 years from 1988 and 1147 subjects of a validation cohort independent of the derivation cohort were followed up for 5 years from 2002. Risk scores were estimated based on the coefficients (β) of Cox proportional hazards model in the derivation cohort and were verified in the validation cohort.

Results In the derivation cohort, the non-invasive risk model was established using significant risk factors; namely, age, sex, family history of diabetes, abdominal circumference, body mass index, hypertension, regular exercise and current smoking. We also created another scoring risk model by adding fasting plasma glucose levels to the non-invasive model (plus-fasting plasma glucose model). The area under the curve of the non-invasive model was 0.700 and it increased significantly to 0.772 ($P < 0.001$) in the plus-fasting plasma glucose model. The ability of the non-invasive model to predict Type 2 diabetes was comparable with that of impaired glucose tolerance, and the plus-fasting plasma glucose model was superior to it. The cumulative incidence of Type 2 diabetes was significantly increased with elevating quintiles of the sum scores of both models in the validation cohort (P for trend < 0.001).

Conclusions We developed two practical risk score models for easily identifying individuals at high risk of incident Type 2 diabetes without an oral glucose tolerance test in the Japanese population.

Diabet. Med. 29, 107–114 (2012)

Keywords community-dwelling Japanese subjects, oral glucose tolerance test, risk models, Type 2 diabetes

Introduction

The number of individuals with Type 2 diabetes mellitus is rapidly growing worldwide [1], probably because population growth, ageing and urbanization are progressing, and the prevalence of obesity and physical inactivity is also increasing [2]. Thus, the burden of Type 2 diabetes and its complications, including macro- and microvascular diseases, is an important concern in global healthcare systems. A practical and effective scheme for the prevention of Type 2 diabetes should be established without delay. Two randomized clinical trials in Europe and the USA have demonstrated that Type 2 diabetes can largely be prevented through diet and lifestyle modifications in individuals at high risk [3,4]. Similar results were also reported in different ethnic populations, such as Japanese [5], Chinese [6] and Asian Indians [7]. In these researches, the estimation of a person's future risk of Type 2 diabetes has depended primarily on identifying impaired glucose tolerance [3–7]. However, the 75-g oral glucose tolerance test integral to a diagnosis of impaired glucose tolerance is relatively costly and inconvenient, and its reliability has been questioned [8]. These facts have stimulated the development of simple scoring methods involving readily available clinical information capable of predicting Type 2 diabetes with equal or better diagnostic properties than impaired glucose tolerance. To date, risk score models have been derived from several Caucasian populations [9–16] and a few Asians populations [17–19] but none have been developed in Japanese.

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The aim of the present study was to develop and evaluate risk score models for the Japanese population to identify individuals at high risk for incident Type 2 diabetes without an oral glucose tolerance test.

Subjects and methods

Setting and participants

Derivation cohort survey

A population-based prospective study of cardiovascular disease and its risk factors has been underway since 1961 in the town of Hisayama, a suburb of the Fukuoka metropolitan area on Kyushu Island, Japan. The age and occupational distributions and nutritional intake of the population were almost identical to those of Japan as a whole based on data from the national census and nutrition survey [20]. In 1988, a derivation cohort survey was performed in the town. A detailed description of this survey was published previously [20]. Briefly, of the 3227 residents aged 40–79 years based on the town registry, a total of 2587 residents (participation rate, 80.2%) consented to take part in a comprehensive assessment. After excluding 82 subjects who had already had breakfast, 10 who were on insulin therapy and 15 because of complaints of nausea or general fatigue during the ingestion of glucose, a total of 2480 subjects completed the oral glucose tolerance test. Among these, 297 subjects with diabetes, 52 for whom there was no measurement of waist circumference and two who died before the start of follow-up, were excluded; the remaining 2129 subjects (894 men and 1235 women) were enrolled in the baseline examination.

The baseline subjects were followed up prospectively from December 1988 to November 2002 by yearly health examinations. Of the baseline subjects, 1935 subjects (793 men and 1142 women) who underwent re-examinations were finally selected for the present study (follow-up rate, 90.9%; mean follow-up period, 11.8 years).

Validation cohort survey

A validation cohort survey was conducted in the same town and in a similar fashion in 2002. The study design of the survey has been described in detail elsewhere [21]. In brief, of the 3896 residents aged 40–79 years, 3000 (participation rate, 77.0%) consented to participate in the examination and underwent a comprehensive assessment. Among them, 178 participants were not administered the oral glucose tolerance test: 100 subjects refused the test, 46 had already taken breakfast and another 32 were receiving insulin therapy for diabetes. Consequently, 2822 subjects completed the oral glucose tolerance test. After further excluding 485 subjects with diabetes, one for whom there was no measurement of waist circumference, one who had no information of family history of diabetes and 1044 who were participants of the derivation cohort, the remaining 1291 subjects (550 men and 741 women) were determined to constitute a validation cohort independent of the derivation cohort.

The subjects were followed up prospectively from December 2002 to November 2007 by yearly health examinations. Of the baseline subjects of the validation cohort, 1147 (473 men and 674 women) who underwent re-examinations were finally selected for the present study (follow-up rate, 88.8%; mean follow-up period, 4.7 years).

Clinical evaluation and laboratory measurements

In both the 1988 and 2002 surveys, clinical evaluation and laboratory measurements were performed in a similar manner. The study subjects underwent the oral glucose tolerance tests between 08.00 and 10.30 h after an overnight fast of at least 12 h. Blood for the glucose assay was obtained by venipuncture into tubes containing sodium fluoride at fasting and at 2-h post-load and was separated immediately into plasma and blood cells. The glucose tolerance levels were defined by the American Diabetes Association criteria in 2003 as follows [8]—impaired glucose tolerance: fasting plasma glucose concentrations of < 7.0 mmol/l and 2-h post-load glucose concentrations of 7.8–11.0 mmol/l; diabetes mellitus: fasting plasma glucose concentrations of ≥ 7.0 mmol/l and/or 2-h post-load glucose concentrations of ≥ 11.1 mmol/l and/or the use of anti-diabetic medications. At the baseline of each survey, waist circumference was measured by a trained staff member at the umbilical level with the subject standing. Body height and weight were measured in light clothing without shoes and the BMI (kg/m^2) was calculated. Blood pressure was obtained three times using a sphygmomanometer in 1988 and an automated sphygmomanometer (BP-203RV III; Colin, Tokyo, Japan) in 2002 with the subject in a sitting position; the average values were used in the analyses. Hypertension was defined as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg and/or current treatment with anti-hypertensive agents.

Each participant completed a self-administered questionnaire covering medical history, anti-diabetic and anti-hypertensive treatments, alcohol intake and smoking habits. Diabetes mellitus in first- or second-degree relatives was taken to indicate a family history of diabetes. Subjects engaging in sports at least three times per week during their leisure time were defined as the regular exercise group.

Follow-up survey of derivation and validation cohorts

An oral glucose tolerance test was performed every year in the follow-up examinations. Subjects from the derivation cohort participated in the follow-up examinations an average of 6.9 times and subjects of the validation cohort an average of 3.2 times. In the follow-up examinations, the diagnosis of incident diabetes was made in a similar way in both cohorts based on the aforementioned American Diabetes Association criteria. During the follow-up, Type 2 diabetes occurred in 286 subjects (145 men and 141 women) in the derivation cohort and 89 subjects (53 men and 36 women) in the validation cohort.

Statistical analysis

SAS version 9.2 (SAS Institute, Cary, NC, USA) and Stata version 10.0 (StataCorp, College Station, TX, USA) software packages were used to perform all statistical analyses. A P-value < 0.05 was considered statistically significant in all analyses.

The Student t-test and χ^2-test were used for the comparison of baseline clinical characteristics between the derivation and validation cohorts. In this study, we used non-invasive risk factors, which were defined as factors that could be measured without taking a blood sample; namely, age (40–44, 45–54, 55–64 and ≥ 65 years), sex, family history of diabetes, central obesity (abdominal circumference ≥ 90 cm in men and ≥ 80 cm in women), BMI (≤ 21.9, 22.0–24.9 and ≥ 25.0 kg/m^2), hypertension, smoking habits (non-smoking, 1–9 and ≥ 10 cigarettes per day), alcohol intake (0, 1–39 and ≥ 40 g of alcohol per day) and regular exercise. Adjusted hazard ratios (HR) and their 95% confidential intervals (CI) were estimated by using the stepwise backward elimination method of Cox proportional hazards model. In the multivariate analysis, we selected independent risk factors for the development of Type 2 diabetes at $P < 0.05$ and composed a non-invasive risk model from these variables. In addition, we created a 'plus-fasting plasma glucose model' in which fasting plasma glucose levels (≤ 5.5, 5.6–6.0 and ≥ 6.1 mmol/l) were added to the non-invasive model. By the use of each scoring model, risk scores for the risk levels of each variable were determined as integral values based on the coefficients (β) of the Cox proportional hazards model, and the sum of the scores was calculated. The probability (P) of incident diabetes for both models was estimated by the following formula: $P = 1 - \{S_0(t)^{exp[b0+b1(x1-mx1)+b2(x2-mx2)+.......+bn(xn-mxn)}$ where P was the probability of developing diabetes within time t; $S_0(t)$ was diabetes-free survival probability at the time t in individuals with the profiles corresponding to the means of the explanatory variables; b1, b2 and bn were coefficients estimated by the model for risk factors, such as x1, x2 and xn; mx1, mx2 and mxn were given as the means. The probability was calculated over a 10-year time frame. In addition, a receiver operating characteristic curve was plotted based on the sum of the scores and the probability of incident Type 2 diabetes by each model, and the area under the curve, which indicates the predictive ability of incident Type 2 diabetes, was estimated for each model. The optimal cut-off points of the sum of the scores for predicting Type 2 diabetes were defined as the maximum combination of sensitivity and specificity. The difference in the area under the curve of the receiver operating characteristic curve between models was estimated using DeLong's method [22]. In the derivation cohort, subjects were divided into deciles of the sum scores and predicted risk derived from each model was compared with observed risk. The goodness of fit, which was assessed by the Hosmer–Lemeshow test [23] was calculated according to a χ^2 distribution with eight degrees of freedom.

Ethical considerations

This study was conducted with the approval of the Kyushu University Institutional Review Board for Clinical Research and written informed consent was obtained from all the participants.

Results

Table 1 shows the baseline clinical characteristics of subjects in the derivation and validation cohorts. The derivation cohort was older than the validation cohort, but the proportion of men was not different between the two. The mean values of abdominal circumference and systolic blood pressure, and the frequency of hypertension were higher in the derivation cohort than in the validation cohort, whereas the mean values of fasting plasma glucose and frequencies of family history of diabetes, smoking habits and alcohol intake were higher in the validation cohort. Other variables did not differ between the cohorts.

Table 1 Characteristics of subjects in the derivation and validation cohorts

	Derivation cohort (n = 1935)	Validation cohort (n = 1147)	P-value
Age (years)	57.2 (10.2)	52.2 (8.6)	< 0.001
Men (%)	41.0	41.2	0.89
Fasting plasma glucose (mmol/l)	5.5 (0.5)	5.7 (0.5)	< 0.001
Two-hour post-load glucose (mmol/l)	6.6 (1.6)	6.7 (1.6)	0.07
Family history of diabetes mellitus (%)	7.4	13.8	< 0.001
Abdominal circumference (cm)	81.4 (9.1)	80.5 (9.4)	0.008
BMI (kg/m^2)	22.9 (3.0)	23.0 (3.3)	0.43
Systolic blood pressure (mmHg)	131 (20)	126 (19)	< 0.001
Diastolic blood pressure (mmHg)	78 (11)	77 (12)	0.051
Hypertension (%)	37.0	26.5	< 0.001
Current smoking (%)	23.2	26.9	0.02
Current drinking (%)	33.4	50.6	< 0.001
Regular exercise (%)	10.6	8.6	0.08

All values are given as the mean (standard deviation) or as percentages.

As shown in Table 2, in the derivation cohort, the univariate analysis showed that all non-invasive risk factors—namely, age, sex, family history of diabetes, central obesity, BMI, hypertension, smoking habits, alcohol intake and regular exercise—as well as the fasting plasma glucose levels were significantly associated with incident Type 2 diabetes. In the stepwise backward elimination analysis, non-invasive risk factors other than alcohol intake remained significant, and we constructed the non-invasive model from these risk factors. In the plus-fasting plasma glucose model, fasting plasma glucose was a significant and independent risk factor for Type 2 diabetes, and its risk score was higher than that of other variables. Both models showed no significant difference between predicted and observed Type 2 diabetes incidence, indicating a reasonable fit by the Hosmer–Lemeshow test (non-invasive model: goodness of fit, χ^2 value = 5.76, P-value = 0.67; plus-fasting plasma glucose model: goodness of fit, χ^2 value = 6.71, P-value = 0.57).

Figure 1 provides a visual presentation of the receiver operating characteristic curves based on the sum of the scores and the probability of incident Type 2 diabetes for the non-invasive and plus-fasting plasma glucose models as well as fasting blood sugar and 2-h post-load glucose values in the derivation cohort. The curve of the sum of the scores was in approximate accordance with that of the probability of incident Type 2 diabetes over 10 years in each model. The area under the curve for the sum of the scores was 0.700 (95% CI 0.667–0.732) and that for the probability of incident Type 2 diabetes was 0.700 (95% CI 0.668–0.733) in the non-invasive model. The optimal cut-off point for the sum of the scores defined by maximizing the sensitivity and specificity to find future Type 2 diabetes was 14 (sensitivity = 62.6% and specificity = 66.5%). In the plus-fasting plasma glucose model, the area under the curve for the sum of the scores and for the probability of incident Type 2 diabetes increased significantly to 0.772 (95% CI 0.742–0.802) and 0.772 (95% CI 0.741–0.802), respectively. The optimal cut-off point for the sum of the scores was 16 (sensitivity = 71.0% and specificity = 69.6%). The area under the curve for the sum scores of the non-invasive model did not significantly differ from that for fasting plasma glucose (AUC = 0.721, P = 0.33) and 2-h post-load glucose values (AUC = 0.677, P = 0.35), while the

Table 2 Risk scores based on non-invasive and plus-fasting plasma glucose (FPG) models for diabetes incidence in the derivation cohort

	Univariate model			Non-invasive model			Plus-FPG model		
Factors		Hazard ratio	*P*	β	Hazard ratio (95% CI)	Score	β	Hazard ratio (95% CI)	Score
Age (years)	40–44	1			1	0		1	0
	45–54	1.48	0.04	0.41	1.51 (1.03–2.22)	4	0.38	1.47 (0.99–2.17)	4
	55–64	1.57	0.02	0.32	1.38 (0.94–2.04)	3	0.30	1.35 (0.91–2.01)	3
	≥ 65	1.1	0.58	0.14	1.15 (0.72–1.84)	1	−0.09	0.92 (0.57–1.48)	−1
Sex	Women	1			1	0		1	0
	Men	1.59	< 0.001	0.35	1.42 (1.04–1.93)	4	0.16	1.17 (0.86–1.60)	2
Family history of diabetes*	–	1			1	0		1	0
	+	2.17	< 0.001	0.73	2.08 (1.48–2.91)	7	0.70	2.01 (1.43–2.83)	7
Central obesity†	–	1			1	0		1	0
	+	1.54	< 0.001	0.32	1.38 (1.01–1.89)	3	0.26	1.30 (0.94–1.78)	3
BMI (kg/m^2)	≤ 21.9	1			1	0		1	0
	22.0–24.9	1.55	0.004	0.25	1.28 (0.93–1.76)	3	0.19	1.21 (0.88–1.66)	2
	≥ 25.0	2.85	< 0.001	0.67	1.95 (1.36-2.81)	7	0.53	1.69 (1.17–2.46)	5
Hypertension‡	–	1			1	0		1	0
	+	2.23	< 0.001	0.68	1.98 (1.55–2.53)	7	0.51	1.66 (1.30–2.13)	5
Smoking (/day)	0	1			1	0		1	0
	1–9	1.23	0.51	0.16	1.17 (0.63–2.18)	2	0.16	1.17 (0.63–2.17)	2
	≥ 10	1.79	< 0.001	0.46	1.58 (1.16–2.16)	5	0.45	1.56 (1.15–2.96)	5
Alcohol intake (g/day)	0	1							
	1–39	1.40	0.01						
	≥ 40	1.82	0.001						
Regular exercise§	–	1			1	0		1	0
	+	0.59	0.02	−0.51	0.60 (0.37–0.96)	−5	−0.38	0.69 (0.43–1.10)	−4
FPG levels (mmol/l)	< 5.6	1						1	0
	5.6–6.0	2.31	< 0.001				0.68	1.97 (1.46–2.65)	7
	≥ 6.1	8.17	< 0.001				1.89	6.61 (4.89–8.94)	19

*Family history of diabetes was defined as diabetes in first- or second-degree relatives.
†Central obesity was determined by an abdominal circumference of 90 cm or more in men and 80 cm or more in women.
‡Hypertension was defined as blood pressure ≥ 140/90 mmHg and/or current treatment with anti-hypertensive agents.
§Regular exercise was determined as engaging in sports at least three times per week during leisure time.

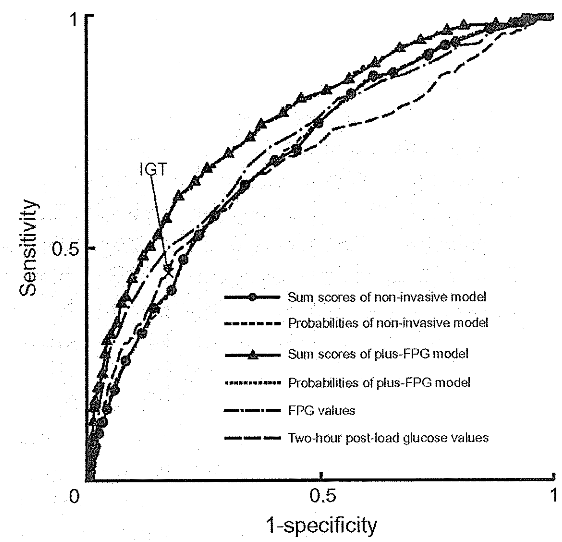

FIGURE 1 Receiver operating characteristics curves of the non-invasive and plus-fasting plasma glucose (FPG) models in the derivation cohort. The cross (×) indicates sensitivity and 1-specificity for impaired glucose tolerance (IGT). The non-invasive model: area under the curve (AUC) for the sum of the scores 0.700 (95% CI 0.667–0.732); AUC for the probability of incident Type 2 diabetes 0.700 (95% CI 0.668–0.733). The plus-FPG model: AUC for the sum of the scores 0.772 (95% CI 0.742–0.802); AUC for the probability of incident Type 2 diabetes 0.772 (95% CI 0.741–0.802). Fasting plasma glucose values: AUC for the probability of incident Type 2 diabetes 0.721 (95% CI 0.687–0.755). Two-hour plasma glucose values: AUC for the probability of incident Type 2 diabetes 0.677 (95% CI 0.687–0.755). The AUCs for the sum of the scores and for the probability of incident Type 2 diabetes of the plus-FPG model increased significantly compared with those of the non-invasive model (both $P < 0.001$).

area under the curve for the sum scores of the plus-fasting plasma glucose model was significantly larger than that for fasting plasma glucose and 2-h post-load glucose values ($P < 0.001$ for both). For impaired glucose tolerance, the sensitivity was 44.8% and the specificity was 82.8%. These findings indicate that the ability of the non-invasive model to predict incident Type 2 diabetes was comparable with that of impaired glucose tolerance, fasting plasma glucose and 2-h post-load glucose values, and the ability of the plus-fasting plasma glucose model was superior to them.

To validate the non-invasive and plus-fasting plasma glucose models of the derivation cohort, the scoring methods were ascertained by applying the scores to the validation cohort. The score distribution of the non-invasive model in the derivation cohort (median 11, interquartile range 7–16) was not significantly different from that in the validation cohort (median 11, interquartile range 7–17) ($P = 0.74$), while the score distribution of the plus-fasting plasma glucose model was shifted significantly to higher levels in the validation cohort (median 15, interquartile range 9–23) than in the derivation cohort (median 12, interquartile range 6–19) ($P < 0.001$). As shown in Fig. 2, the 5-year cumulative incidences of Type 2 diabetes increased significantly with elevating quintiles of the sum scores of the non-invasive and plus-fasting plasma glucose models in the validation cohort (both P for trend < 0.001). In this cohort, the area under the curve for the sum scores of the plus-fasting plasma glucose model for incident Type 2 diabetes (AUC = 0.777; 95% CI 0.727–0.827) was significantly larger than that of the non-invasive model (AUC = 0.691; 95% CI 0.633–0.749) ($P < 0.001$), but did not significantly differ from that for fasting plasma glucose (AUC = 0.777; 95% CI 0.720–0.833) ($P = 0.99$) or 2-h post-load glucose values (AUC = 0.843;

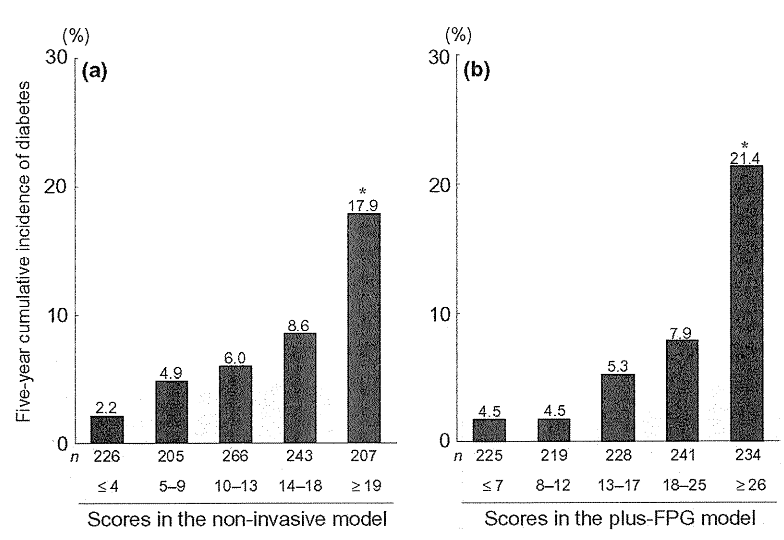

FIGURE 2 Estimated 5-year cumulative incidence of Type 2 diabetes by quintile of prediction scores of the (a) non-invasive and (b) plus-fasting plasma glucose (FPG) models in the independent validation cohort. *P for trend < 0.001.

95% CI 0.800–0.886) ($P = 0.07$). For impaired glucose tolerance, the sensitivity was 70.8% and the specificity was 80.9%.

Discussion

In the present study, we developed two practical risk scoring methods, the non-invasive and plus-fasting plasma glucose models, for prediction of incidence of Type 2 diabetes in Japanese subjects. The variables included in the non-invasive model were age, sex, family history of diabetes, central obesity, BMI, hypertension, smoking and regular exercise, and the plus-fasting plasma glucose model was composed of these factors and fasting plasma glucose levels. The ability of the non-invasive model to predict Type 2 diabetes was comparable with that of impaired glucose tolerance, and the plus-fasting plasma glucose model was superior to the non-invasive model and impaired glucose tolerance as well as fasting plasma glucose and 2-h post-load glucose values. Furthermore, both scoring models were tested in the validation cohort established at a different time, and their utility for identifying persons at high risk of Type 2 diabetes was confirmed. These models could provide an innovative approach for detecting Japanese subjects at high risk of developing Type 2 diabetes in clinical and public health settings.

There are a number of important requirements which must be met by any potential risk assessment model for Type 2 diabetes. First, the risk score model must be appropriately matched to the lifestyle of the ethnic group being studied. The reported risk prediction models for Type 2 diabetes were almost all developed in Caucasians [9–16], with only a few being developed for Asians [17–19] and none being designed specifically for Japanese. Our risk scoring methods are thus the first risk prediction models for incident Type 2 diabetes for Japanese. Second, the scoring method should be appropriate for a primary medical care setting and should allow a non-professional person to perform self-assessment. Some of the reported models have not met this requirement, as the scoring methods were not simplified by using integer point values [10,14,17]. Our two scoring models are easy to use and their scoring methods are simple enough to be calculated using only a pencil and paper through the adoption of integer point scores.

A non-invasive risk prediction model is attractive because it is more convenient and less expensive compared with models that rely on blood tests. Some risk score models for Type 2 diabetes have required the values of biomarkers other than glucose [12,17,19,24]. However, the inclusion of blood test data might not be practical in some situations, as such tests are not easily affordable. Furthermore, it is noteworthy that the ability of our non-invasive model without laboratory tests was almost as good as that of impaired glucose tolerance in predicting the 10-year risk of diabetes. Recent randomized controlled trials have shown that the incidence of diabetes can be decreased significantly by interventions in individuals at high risk of developing Type 2 diabetes; namely, those with impaired glucose tolerance [3–7]. Our non-invasive model would easily identify individuals at high risk of incident Type 2 diabetes without an oral glucose tolerance test in community healthcare and clinical practice.

The predictive performance and discriminative ability of our non-invasive model estimated by the receiver operating characteristic curve was relatively inferior or comparable with those developed among Caucasians (AUC in Caucasian cohorts 0.71–0.85; AUC in our cohort 0.70), although the factors making up the model were similar among these scoring models [9,11–13,16]. It is not clear why the area under the curve in our non-invasive model was smaller than that in the other studies, but the disparity may be related to differences in the aetiology of Type 2 diabetes among races. An epidemiological study has shown that the levels of insulin secretion and resistance differ among various ethnic groups in the USA [25]; Asians had lower levels of insulin secretion compared with other ethnic groups, while Caucasians were more insulin-resistant than Asians. In addition, Japanese individuals with diabetes were found to have lower BMI levels compared with Western individuals with diabetes [26]. Thus, it is speculated that impaired insulin secretion, rather than insulin resistance, plays an important role in the development of Type 2 diabetes among Asian populations. In our risk score models, most of the included factors were predominantly proxy of insulin resistance, and the data on insulin secretion, which is known to be determined mainly by genetic factors [27], were limited. Additionally, the differences in definition of diabetes, distribution of risk factors and changes in risk factors and their distributions over time may contribute to the disparity in the area under the curve among races.

In our study, combining the information on fasting plasma glucose levels with the non-invasive model significantly increased the predictive ability of incident Type 2 diabetes and the fasting plasma glucose concentrations at baseline were the single largest contributor to the risk of diabetes mellitus. Other reports have similarly shown that fasting plasma glucose was a strong predictor of incident Type 2 diabetes [12,16,28]. It is expected that people whose fasting plasma glucose concentration is already close to the diagnostic threshold for Type 2 diabetes are likely to cross the threshold in the near future. Thus, it may be recommended that individuals with higher risk scores in the non-invasive model undergo fasting plasma glucose measurement. However, to date, there is no clear evidence to suggest which strategies are most effective at identifying individuals at high risk and at preventing diabetes in these individuals. Further research into cost-effectiveness for identifying and treating individuals at high risk of diabetes is needed, considering the stepwise strategies incorporating non-invasive risk scores.

Our findings also help to clarify the pathogenesis of incident Type 2 diabetes in Japanese individuals. First, in our study, both BMI and waist circumference independently contributed to risk discrimination for Type 2 diabetes. BMI is an indicator of overall adiposity, whereas waist circumference is highly correlated with visceral adipose tissue, which actively secretes adipocytokines and other vasoactive substances that are associated with the risk of developing Type 2 diabetes [29,30]. Thus, BMI and waist