COMPARATIVE RESEARCH OF AUDIT TOOLS ON BUILT ENVIRONMENT FOR ACTIVE LIVING

Nowadays, chronic non-communicable diseases have impacted the overall public health level of societies and caused severe socio-economic burden. Empirical studies have revealed that physical activities can promote active living and help prevent and heal non-communicable diseases. Evaluation of built environment factors associated with physical activities is the precondition of promoting active living through environmental planning and design. This paper focuses on environmental audit tools related to physical activities, reviews the background, interests, and progress of international research, and compares the option forms, main measured factors, scoring methods, and application suitability of 26 audit tools. It then categorizes these audit tools into the ones for community, open space, and other scenarios, and examines their indicator items respectively. The paper concludes a preparation pattern across various audit tools, and identifies that facilities, accessibility, visual quality, and safety are the indicators most commonly measured. This paper attempts to introduce international experience of developing, analyzing, and verifying audit tools to inform Chinese research and practice and provide references for evaluating the design and construction of healthy cities or communities.

KEYWORDS
Audit Tool; Built Environment; Physical Activity; Health Impact Assessment; Urban Design; Quick Environmental Assessment

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1 Introduction

Promotion of a nation’s health level, both physical and mental, is significant for guaranteeing people’s well-beings. Chronic non-communicable diseases (chronic diseases for short) such as obesity, cardiovascular disease, and depression impact people’s life seriously. Since 2000, governments and institutions in developed countries have proposed guidelines for advocating active living to cope with such public health issues, including the Active Design Guidelines by the United States[1] and the Active by Design: Designing Places for Healthy Lives by the United Kingdom[2]. Active living embraces more physical activities, such as walking and cycling, or active recreation and fitness[3][4]. Reported by World Health Organization (WHO), 60% of chronic diseases are caused by unhealthy lifestyles, of which physical inactivity is the fourth leading factor for premature death worldwide and has resulted in a rise of Chinese people’s medical expenses[5]. Published in The Lancet, Scott A. Lear’s study of residents from 17 countries evidenced that a higher frequency of physical activity was associated with a lower risk of diseases; increasingly, physical activity has been proved a simple and low-cost method for promoting public health globally[6].

WHO also reported that insufficient physical activity is related to the lifestyles influenced by rapid urbanization[7], in which the urban environment has been dominated by motor vehicles, reducing people’s physical activity opportunities and threatening their mental and physical health[8][9]. In the 19th century, urban planning, design, and management played a critical role of controlling communicable diseases in many countries[10], demonstrating its great potential to safeguard public health. Nowadays, public health problems caused by physical inactivity can be mitigated through the improvement of urban fabrics and architectural spaces. Urban planners and designers ought to promote citizens’ active lifestyles with environmental interventions, and to eventually improve the overall health level of the nation.

In recent years, a great number of studies among various fields together prove that the quality of built environment significantly influence people’s physical activities and recognize the potential positive effects of relevant environmental policies[11][17]. Specifically, environmental factors, such as mixed land use level, land development density, accessibility of destination, connectivity of urban road network, amenity / supporting facility coverage, might all impact physical activities. It makes the measuring, identifying, and diagnosing of these factors prerequisite[18] to effectively intervene physical activities with environmental approaches, which is
持续性。当前国际学界主要采用自我报告、GIS及相关便携设备、建成环境量表（以下简称量表）三类工具来度量潜在环境要素。其中，量表因在调研成本与数据技术门槛、度量的可靠性、适用性等方面拥有较好的平衡度而得到了广泛的发展和应用。一项对比研究表明，精确且系统的量表在理解错综复杂的环境-体力活动关系及作用方式方面具备优势。同时，其相对标准化的指标体系和工作流程对于注重可行性与推广性的规划设计领域尤为重要。

然而，尽管中国学者已逐渐开始开展相关研究并呼吁将“健康”要素纳入城市规划的考量，关于如何改善建成环境以促进体力活动的实证研究在城市规划领域依旧匮乏。通过全球最大的中文数据库中国知网（CNKI）检索关键词“体力活动”和“建成环境”，发现中国学者的相关实证研究主要发表于体育科学类与公共卫生类期刊，研究内容以居民主观感受为主，客观测度环境的研究较少，且所选指标系统性和精确性不足，其应用方式主要为改编或直接引用国际上已发展成熟的量表。鉴于此，分析和比较量表制定的目的、类型、结构、分析方法以及对于实践的指导意义，并理解这种工具体系的价值，有助于中国研究者进行对比和参照。

2 研究范围与研究方法

2.1 体力活动与建成环境的定义

体力活动是指任何由骨骼肌收缩引起的导致能量消耗的身体活动，通常借助时间、频率、强度、类型和模式等刻画其特征。体力活动按强度可分为高强度、中等强度、低强度；按类型可分为休闲性与交通性。目前，相关研究常用体力活动水平来表征环境对健康的支持情况，并以此作为相关决策的制定依据。

建成环境是指人为创造的各类物质环境空间的总和，人的行为模式亦受其影响。特里·皮克瑞基于社会-生态模型建立了整合建成环境要素与个体、群体体力活动水平的理论框架，从而将建成环境对居民健康的影响置于动态的但可被理解的复杂系统中，为通过干预环境促进体力活动的策略研究提供了理论基础。

2.2 测度建成环境的量表工具

量表是一种综合了多项指标的测度工具，它建立在实验研究和经验性评估的基础上，以相对客观的角度、简单快捷的方法度量环境，具有严格的编制、检验和使用流程，为进行高效对比分析提供了数据基础。

本研究讨论的量表特指可系统化而客观地度量影响体力活动水平的潜在环境要素特征的量表。自1998年詹姆斯·埃默里等人制定WABSA also essential to the Health Impact Assessment. Measuring and identifying environmental indicators requires high reliability, comprehensiveness, and consistency of data. In international academia, environmental indicators are often measured with Self-reports, GIS and related portable devices, and Built Environmental Audit Tools (audit tools hereafter), among which the audit tools see a wider application because of their favorable equilibrium in cost, user-friendliness, reliability, and applicability. A comparative study shows that audit tools of a higher accuracy and systematism are more suitable for understanding the complicated relationship between built environment and physical activities as well as associated working mechanisms. Furthermore, based on a standardized indicator system and workflow, audit tools show a high feasibility and great potential for a broader application in the field of urban planning and design.

Although health related topics have been receiving increasing attention among Chinese researchers and urban planners, empirical studies on promoting physical activity through the improvement of built environment are still insufficient. By searching the China National Knowledge Infrastructure (CNKI) database with keywords of “体力活动” (physical activity) and “建成环境” (built environment), gaps are found as follows: First, existing empirical studies are mainly discussed in the fields of Sports Science and Public Health. Second, most studies focus on describing residents’ subjective perception instead of scientific measurements. Third, the poor accuracy and comprehensiveness of indicators make these studies nothing but adaptations or repeating applications of internationally recognized audit tools and fail to conclude solid research findings. Therefore, a holistic analysis and comparison of the objectives, type, structure, analysis methods, and practical guidance of different audit tools will help Chinese researchers enhance and develop applications of audit tools.
2.2 Audit Tools for Built Environment Measurement

Based on empirical research and evaluation, audit tools integrate multiple items to measure the environment in a relatively objective, simple, and fast way with rigid procedures of preparation, verification, and application, quantifying environmental information for further comparative analyses.

Audit tools discussed in this paper particularly refer to the ones that can systematically and objectively measure the factors of built environment which would potentially influence the physical activity level. Since WABSA was developed in 1998 by James Emery et al.,[136], scholars in Public Hygiene and Urban Planning have developed hundreds of audit tools for built environment measurement at varied scales for different scenarios. An overall examination of existing audit tools will help scholars understand their application differences and suitability (Fig. 1).

In terms of scale, macro audit tools focus on the overall layout and structure of urban blocks and communities, or even whole cities[37][38]; meso-scale audit tools are often used to measure spatial fabrics, such as the number of cul-de-sacs and road intersections; while micro-scale ones are designed to discern the environmental factors that may have effects on physical activities by describing people’s experience and perception in the spaces.[39]

With regard to the purposes, audit tools are developed mainly for three reasons: the ones for academic research require high accuracy and reliability[40][41]; the ones for decision-making purpose[42] usually cover all kinds of environmental factors on macro- and meso-scales; and the ones for community building are concise and easy to operate, providing guidance for active bottom-up practice[43][44].

As to application scenarios, audit tools are often used to measure communities, open spaces, streets, workplaces, cities, etc., and the first two are mostly studied. Early audit tools were mainly developed for meso- and micro-scale scenarios such as urban streets; they were then applied to support decision-making and community management. Studies of audit tools for city-scale scenarios were carried out relatively late[45].
Current audit tools see a diversity in structure and indicator system. Since relevant study in China is still staggering in its primary stage, and the existing research consists of individual studies such like community measurement\(^{[46][47]}\). This paper takes scenario type as a clue to review the characteristics of various audit tools.

2.3 Research Method

In July 2018, authors searched for journal articles with the keywords shown in Figure 2 in CNKI, Web of Science, and Google Scholar, reviewed their titles and abstracts to screen out irrelevant studies; the references of selected literature were further examined to source more relevant articles. Additionally, the research findings of audit tools from the Active Living Research website, an influential authority among academia and policymakers, sponsored by the Robert Wood Johnson Foundation (RWJF), were also included in this paper. By doing so, a total of 130 articles and 46 audit tools were collected, and the English names and their abbreviations of

| 城市 | Urban
| 环境 | Environment |
| 空间 | Space |
| 街道 | Street |
| 绿地 | Green Space |

| 工作场所 | Workplace |
| 增删未度量环境要素的量表以及摘要未提及使用量表度量环境要素的文献。 |
| Audit tools not used for measuring built environment and articles not mentioning audit tool measurement of built environment in their abstract were eliminated. |
| 130篇文献，46份量表 |
| 130 articles，46 audit tools |

| 第二次检索 | Second-round search |
| 数据库 | Databases: Web of Science, Google Scholar |
| 关键词: 46份量表的英文名称及缩写 |
| Keywords: full English names and abbreviations of the 46 audit tools |

| 69篇文献，26份量表 |
| 69 articles，26 audit tools |

| 近期参考文献中与研究内容相关的文献。 |
| References were examined for tracing more relevant articles. |
| 73篇文献，26份量表 |
| 73 articles，26 audit tools |
eligible audit tools were used as keywords for further literature searching in Web of Science and Google Scholar.

This study searched for articles on audit tools for environmental measurement of physical activity published from January 1988 to July 2018, and excluded those not mentioning any names of audit tools, or studying social or nutritional environments, or merely observing physical activities without discussion about built environment. Finally, 26 audit tools — 21 from the United States, two from Australia, two from Canada, and one from the United Kingdom — and 73 articles were selected (Fig. 2).

3 Research Findings

3.1 Overview

The selected 26 audit tools can be classified by scenario type into five categories (Table 1): 10 audit tools for communities, 8 for public open spaces, and 8 for urban streets (including paths, trails, and roads), workplaces, and cities. The published year, country of origin, number of indicator items, option forms, main measured factors, scoring method, reliability and validity tests, auditor, and target group of the audit tools are examined.

The number of indicator items among the audit tools varies significantly from 14 to 751\(^{[48]}\). Environmental indicators of public open spaces are much more than others, while those for streets have fewer items because the environment of such scenarios is relatively simple. Tools with more indicators can be used to conduct a relatively comprehensive measurement for the environment to reveal its subtle associations between physical activities and the built environment, but would cost more time for data collection and analyses as well as interference screening. Audit tools with fewer items are easy and quick to operate, but often lack systematism and have limited applicability.

Option forms of audit tools include choice questions (e.g., yes / no question, ordered and unordered category choice question, etc.), counting questions, and open-ended questions, according to which, audit tools can be further divided into analytic and checklist ones. Analytic audit tools are usually in form of multiple options, usually for academic purpose, while checklist audit tools are often simply designed in form of binary response and ordered category choice questions (such as ANC), making it more suitable for decision-makers or community stakeholders to learn the basic profile of the targeted environment.

Average time spent with different audit tools fluctuates and the difference may accumulate up to 4 hours\(^{[49][50]}\). As the most time-consuming audit tool, TCOPPE costs 90 minutes for one
### 表1: 衡量建成环境要素的量表信息

| 量表名称（缩写） | 目标围/量表名称(缩写) | 发表时间 | 指标数量 | 选择设置 | 主要度量要素 | 计算方式 | 结果 | 评估者 | 需求时间 | 是否为更新版本 | 导向群体 |
|-----------------|----------------------|----------|----------|----------|----------------|----------|------|---------|----------|-----------------|----------|
| I. | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
### 社区类量表

| 量表名称 | 发表时间 | 国家 | 量表名称(缩写) | 发表时间 | 国家 | 量表名称(缩写) |
|---------|----------|-----|---------------|----------|-----|---------------|
| AAT & CAT / 2003 / U.S. | | | Analytic Audit Tool and Checklist (AAT & CAT) | 2003 / U.S. | | |
| PARA / 2007 / U.S. (ANC is not analyzed in this paper) | | | Active Neighborhood Checklist (ANC) | 2007 / U.S. | | |
| BRAT - DO / 2005 / U.S. | | | The Wisconsin Assessment of the Social and Built Environment (WASABE) | 2014 / U.S. | | |
| WASABE / 2014 / U.S. | | | The Wisconsin Assessment of the Social and Built Environment (WASABE) | 2014 / U.S. | | |

#### 表1：衡量建成环境要素的量表信息

| 量表名称 | 领域 | 指标数量 | 选项设置 | 主要度量要素 | 计算方式 | 信效度检验结果 | 评估者 | 需求时间 | 是否为更新版本 | 导向群体 |
|----------|----------|----------|----------|--------------|----------|----------------|--------|-----------|----------------|----------|
| AAT & CAT / 2003 / U.S. | Community audit tools | 115 | BR, UC, MC | BR, UC, MC | Separate analysis | PA ≥ 70% | 4 ~ 8 | No | All groups |
| PARA / 2007 / U.S. | Open space audit tools | 37 | DC | DC | Summary index | K ≥ 0.77 | 10 | No | All groups |
| BRAT - DO / 2005 / U.S. | | 124 | BR, UC | BR | Summary index | PA ≥ 70% | No | No | All groups |
| CPAT / 2010 / U.S. | | 32 | BR, UC, MC | BR, UC, MC | Separate analysis | 1) PA ≥ 70% | Yes (App) | No | All groups |

续表见下页 / Continued
| 量表名称（缩写） | 指标数量 | 选项设置 | 主要度量要素 | 计算方式 | 信效度检验结果 | 评估者 | 需求时间 | 是否为更新版本 | 导向群体 |
|---------------|-----------|----------|--------------|----------|----------------|--------|----------|----------------|----------|
| U.S. Walkability (MIUDQRW) / 2006 | 744 | BR, UC | 主要特征，特定功能场所、亲水性空间和活动设施和游憩场所 | 无记录 | 信度：K > 0.6；效度：不涉及 | 相关专业人士 | 10~258 (平均时间：67.3分) | 是 | 无区分 |
| The Parks, Activity and Recreation among Kids (PARK) Tool / 2015 | 92 | BR, OC, UC | 公园活动，环境质量，公园服务，安全性，整体印象 | 无记录 | 信度：K > 0.77；效度：不涉及 | 相关专业人士 | 10 | 否 | 青少年 |
| Public Open Space Tool [POST] / 2004 | 43 | BR, OC, QC | 公园活动，环境质量，安全性能，便利设施 | 无记录 | 信度：PA；6.4%~97.9%；ICC：0.36~0.93；K：0.19~1.00 | 相关专业人士 | 16~28 | 否 | 无区分 |
| Neighborhood Green Space Tool (NSST) / 2012 | 39 | BR, OC, Counting | 可达性，娱乐设施，便利设施 | 无记录 | 信度：ICC；0.58~0.95；整体为0.73 | 相关专业人士 | 7~15 (平均时间：11分钟) | 否 | 无区分 |
| Rural Active Living Assessment [RALA] Tool / 2009 | 81 | BR, OC, UC | 城镇活力特征，休闲设施，项目和政策，街道特征 | 无记录 | 信度：PA；91.9%；K：0.78 | 相关专业人士 | 3~25 (平均时间：9分钟) | 否 | 无区分 |
| Measurement Instrument for Urban Design Quality Related to Walkability (MIDQRW) / 2006 | 27 | Counting | 步行环境通透度，复杂度 | 无记录 | 信度：ICC；0.40~0.59 | 相关专业人士 | 否 | 无区分 |

表1: 量表工具信息
Table 1: Information of audit tools for measuring built environmental factors

| Open space audit tools |
|------------------------|
| 城市审计工具 |
| City audit tools |

续表见下页 / Continued
表1: 衡量建成环境要素的量表信息

| 量表名称 (缩写) / 刊物 | 指标数（计分/发表年份） | 选项设置 | 主要测量要素 | 计算方式 | 信效度检测结果 | 评估者 | 调查时间（单位：分钟） | 是否为更新版本 | 导向群体 |
|-----------------------|------------------------|----------|---------------|----------|-----------------|--------|-----------------------|----------------|----------|
| 街道类量表 | Street audit tools | | | | | | | |
| 街道环境量表（PEAT） / 2005年 / 美国 | 36 | BR, OC, UC | 街道口，便道设施，维护及美观程度 | 分析比较 | 信度: ICC > 0.52, 40%的指标 | 相关专业人员 | NR | 否 | 无区分 All groups |
| 步行与骑行可持续性评估（WASA） / 1999年 / 美国 | 步行: 15 骑行: 27 W: 15 B: 27 | W: BR, OC, UC; B: BR, OC, Counting | 步行街道基本特征、骑行街道基本特征、道路缓冲带、安全性 | 实证组合模型 | 信度: ICC (W) = 0.79, ICC (B) = 0.90 | 相关专业人员 | NR | 否 | 无区分 All groups |
| 儿童步行、生活方式和环境的国际研究（ICSCLE） / 2015年 / 美国 | 49 | BR, OC, UC, DEQ | 路面特征、交通安全、便利设施、人体安全 | NR | 无记录 | NR | 否 | 老年人 The aged |

工作场所类量表

| 工作场所量表 | Workplace audit tools | | | | | | |
|-----------------------|------------------------|----------|---------------|----------|-----------------|--------|-----------------------|----------------|----------|
| 儿童和青少年的视野调查工具（TCOPPE） / 2013年 / 美国 | 37 | BR, OC, Counting | 步行和骑行环境、运动和游乐设施 | 汇总指数 | 信度K = 0.80~0.86, 42%的指标, K = 0.61~0.79, 54%的指标 | 相关专业人员 | NR | 否 | 无区分 All groups |
| 成人行走和自行车路径审计工具（WWAT） / 2009年 / 美国 | 14 | OC | 人行道设施、人行道与机动车车道的冲突、道路缓冲带、可及性、美学性、遮盖程度 | 实证组合模型 | 信度: ICC = 0.61~0.79, K = 0.20~0.40, 40%的指标 | 相关专业人员 | NR | 否 | 无区分 All groups |

注: 1. 不同量表的开发文献记录指标数量的标准不同，本表中“指标数量”是指指标数表中指标的响应时间的总数。不包含标
记不采取“无记录”或有其他标记的项目。对于涉及百分比响应的量表，指标数以百分比为单位。
2. 尊重名称仅在其首次出现的名称，不包含之后修订版名称。
3. 量表名称按照其表头出现的名称，不包含之后修订版名称。
4. 表所列的专业术语，仅作为参考。
5. 量表名称和专业术语的分类取决于量表的性质。
6. 量表名称仅存在于出现的名称，不包含之后修订版名称。
7. 量表名称按照其表头出现的名称，不包含之后修订版名称。
8. 相关专业人员无区分，评估者无区分，导向群体无区分。

NOTES
1. The literatures of audit tools studied in this paper adopt varied methods for counting the number of indicator items. In this table, “Number of indicator items” refers to the total number of their responses. Tags (e.g., auditor ID, segment ID, codes, etc.) are excluded. The item is counted by combination response.
2. The audit tools listed in this table are recorded as their initiative names, while the names of their updated versions are not mentioned.
3. The scoring methods in this table are sorted from relevant literatures, official documents, and empirical studies.
4. This table shows the corresponding average and / or range of time spent of each tool to provide references for future studies.
5. Reliability in this table refers to inter-auditor reliability unless otherwise stated. Reliability test is conducted for specific research needs, where generally open-ended questions are not included. The reliability coefficient ranges from 0 to 1, and the closer to 1, the higher the reliability is. A coefficient higher than 0.4 means acceptable reliability.
6. Abbreviations used in this table include: BR = binary response; OC = ordered category; UC = unordered category; MC = multiple choices; OEQ = open-ended questions; PA = the percentage agreement; K = Kappa coefficient; ICC = intra-class correlation; Person = Person coefficient; PAU = practice advocates; CIs = community stakeholders; NA = not reported; NA = not applicable.
measurement on average, while most of rest cost no more than 20 minutes typically. The average time spent is impacted by the size and land use of the targeted area, the indicator coverage and the complexity of audit tool’s structure.

To sum up, audit tool applications require considerations on the study object, scale, purpose, and auditor’s needs.

3.2 Validity and Reliability Tests

In general, standardized audit tools should go through validity and reliability tests before application, and their items and structure would be calibrated according to the feedback.

Validity represents to the extent of accuracy of an audit tool for reflecting its research purpose and hypotheses. Only 7 of the above 26 tools have conducted validity test. Compared with the proven audit tools in Medical Sciences, the validity test of audit tools on built environment is just primarily explored and lacks a consistent benchmark \[51\]: most of them are simply developed by experts’ experience or with GPS data, only a few of which have systematically gone through validity test for correlation analysis of environmental factors and physical activity level \[52\]. The audit tools without formal validity tests often ensure their validity by identifying environmental factors through extensive literature reviews, open-ended qualitative surveys, referencing to published audit tools, etc. Enhancing and improving validity test for audit tools on built environment needs more efforts in strengthening empirical studies across regions to identify the commonly recognized environmental factors and to adjust and upgrade the frameworks of audit tools.

The consistency of the measurement results, i.e., reliability, is critical to the standardized application of audit tools on built environment. \[53\] Because of auditors’ bias, scorer reliability is usually adopted to examine the consistency of audit tools. Except of WRATS, all the other collected audit tools have conducted reliability test with various methods. Tested with Kappa coefficient (K) and intra-class correlation coefficient (ICC), most items in the audit tools have acceptable reliability (K > 0.4, ICC > 0.4); the test results of percentage agreement also show good reliability (≥ 75%). A comparison of all the test results further reveals that the reliability of objective and simple items are higher than that of subjective and complicated ones \[50\][54].

Inevitably, some items see a low reliability yet are considered highly correlated to people’s physical activities, such as canopy cover, maintenance status of roads and facilities. In this instance, researchers usually improve the overall reliability of audit tools by adjusting the indicator selection or structure, and auditor training \[50\][54].
3.3 计算方法
量表中常用的计算方法为分析单项指标，或将多项指标得分汇总以获取整体指数。在分析单项指标时，研究者需仔细甄别各项要素，再根据实际情况确定统计方法。该形式易于回溯和比较每个环境要素的状态，并借此提出相应改进措施。如安德鲁·T·卡钦斯基使用CPAT量表对美国堪萨斯市的公园环境要素进行度量，并使用逻辑回归分析每个指标与体力活动的关系。发现运动场、棒球场、游泳池、喷水池和湖泊等特定公园设施能不同程度地影响体力活动。在分析整体指数时，研究者除了需考虑单项要素外，更要精心拟定计算模型——通常为简单汇总模型和加权组合模型。简单汇总模型能快速确定研究区域环境对体力活动的整体支持情况，加权组合模型则按照对于体力活动的支持程度强弱对各类环境要素赋予权重，使总指数更具科学性。据此模型得出的整体指数将环境对体力活动的支持程度分为不支持、较支持、支持三个等级。例如，安德鲁·L·丹嫩贝格使用WWAT量表度量一个工作场所，詹姆斯·艾默里等和威廉·汉森等使用WABSA量表度量街道等均展现了整体指数表征环境对体力活动的支持程度。

3.4 各类环境量表指标及相关文献对比研究
即使针对同一类型场所，不同量表的环境要素及指标、结构与计算方法仍非常多样化。因此，选择或编制环境量表时不仅要关注场所类型及场所的整体特征，还应注意其中各类环境要素，才能更准确地挖掘环境对体力活动的潜在影响。本文对不同类别量表的指标内容进行重新分类以构建相近的环境要素类别，并就社区、开放空间、其他环境三类分别进行对比。

3.4.1 度量社区的量表工具
社区类量表发展较早且已广泛应用，其各项指标重新分类后可归纳为10类环境要素（表2），这10类要素中的指标几乎涵盖了所有能够促进体力活动的社区环境特征。将各量表中各类要素所包含的指标数量占比图示化（图3），根据要素出现频次可探讨各类要素的优先度，以此了解各量表的侧重方向。

3.3 Scoring Methods
Single item scoring and overall index analysis by summing up multiple item scorings are commonly used methods for the calculation in audit tools. For single item scoring, auditors should carefully examine the characteristics of each factor and determine statistical methods. This approach is suitable for a quick profile and comparison between the status of each environment factor, which helps researchers propose improvement approaches correspondingly. For example, by using CPAT to measure environmental factors of parks in Kansas City, USA and analyzing the association between each item and physical activity with logical regression, Andrew. T. Kaczynski proved that playgrounds, baseball fields, swimming pools, spray ponds, lakes, and other park facilities influence users' physical activities at varying degrees. For overall index analysis, auditors should carefully select computational models — simple summary model or weighted combination model. The simple summary model can be used for a quick measurement of the environment's support degree to physical activities, while with the weighted combination model, various environmental factors are weighted according to their support degree to physical activities to gain a scientific overall analysis of index: not supportive, relatively supportive, or supportive. This model was applied in the study by Andrew L. Dannenberg to measure a workplace with WWAT, and by James Emery et al. and William Hansen et al. to measure urban streets with WABSA.

3.4 Comparative Study of Audit Tool Items and Relevant Literature
For a same scenario, the environmental factors and items, structures, and scoring methods of different audit tools may be varied. Besides of the type and overall characteristic of a given place, researchers should also investigate all the environmental factors to evaluate the potential effects of the environment on physical activities. In this paper, indicators in different audit tools were reclassified to fit in audit tools for communities, open spaces, and other scenarios, and a comparison study is made.

3.4.1 Community Audit Tools
Community audit tools have a longer development history and a wider application, the indicators of which cover 10 categories of environmental factors that would promote physical activities in communities (Table 2). The distributions of indicators to various factors in each audit tool are shown in Figure 3. The occurrence frequency of factors evidences their priorities in each tool, from which audit tool's suitability can be learned.
### 表2：各类环境要素定义

**Table 2: Definitions of environmental factors in different types**

| 要素   | 具体解释   | 涵盖的指标（不完全列举） |
|--------|------------|---------------------------|
| 基本环境特征 | 结构特征 | Road slope, height of buildings, and traffic conditions (e.g., the forms of roundabouts, number of motorized lanes, etc.) |
| 设施   | 独立活动     | 健身活动设施, 门廊, 围栏, 车位, 自行车架等 |
| 可达性   | 人们能够轻易进出特定区域及使用其中特定设施的能力，包括促进和限制可达性的指标 | Connectivity of sidewalk, presence of highways and obstacles, etc. |
| 美观要素 | 特指增添或破坏环境吸引力的特征 | Special buildings, special sculptures, presence of garbage, etc. |
| 安全要素   | 包含可能保障或威胁人身安全的环境指标 | Presence of graffiti and abandoned cars, adequate lighting, etc. |
| 维护情况  | 整体状况 | The maintenance status of buildings, landscape features, sidewalks, etc. |
| 标识     | 主要标志 | Safety warning signs, and traffic control streamers, etc. |
| 土地利用混合度 | 其他目的地 | Commercial buildings (such as restaurants, cafes, and shopping malls), churches, libraries, etc. |
| 社会环境   | 人群活动 | All kinds of activities, traffic volume, air pollution, noise, etc. |
| 主观评估  | 对整段道路步行和骑行推行的判断 | An overall assessment of the suitability for walking and cycling along a road |

3. **图2：社区量表内指标占比分布**（因未搜索到ANC量表电子文献，本图未对ANC进行分析。）
As is shown in Figure 3, indicators of mixed land use, basic environmental characteristics, and safety are commonly found across the community audit tools, where the number of the former two items predominates, ranging from 33.33% (PIN3) to 84% (SWEAT), with empirical studies proving a higher level of safety and mixed land use can increase the community vitality \cite{62,63}. The least mentioned factor is subjective assessment. For example, indicators like “attraction of walking” are difficult to quantify, therefore sometimes supplementary subjective measurement is required. Subjective assessment is only included in four audit tools and sees a low reliability \cite{64,65}, so as the social environment factor (e.g., the noise occurs randomly and the measurement results vary at different periods of time) which is rarely adopted by most audit tools. Such social environment factors may be improved indirectly through urban planning and design approaches.

Among all the community audit tools, IMI and MAPS witness a widest coverage of indicators and a relatively high reliability. IMI is the most widely used community audit tool \cite{66-68}. MAPS excludes subjective assessment and has four versions: the full version (including 200 indicator items) is mainly used for measuring micro-scale environmental factors; the abbreviated version (54 items) is mostly used in relevant studies \cite{69}; MAPS-mini (18 items) is mainly employed for simple measurement and welcomed by nonprofessional auditors \cite{43}; MAPS-global allows for international comparison, whose reliability has been tested in five countries \cite{70}. NALP and SWEAT cover the fewest indicators. Specifically, items in NALP are concise and representative for quick assessment of the support degree of the given environment \cite{71}; SWEAT is developed for the measurement of aged users' physical activities and designed especially with safety considerations \cite{53}.

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3.4.4 Open Space Audit Tools

After reclassifying items of the eight open space audit tools, two factor categories that are different from those of community audit tools were identified, namely surrounding environment and incivilities. Indicators of surrounding environment measure basic environmental factors within a certain range around an open space. Incivilities refer to the uncivilized behaviors (such as littering) or unpleasant things (such as pet's excrement) observed in the open space. The distributions of indicators in each open space audit tool are sorted as Figure 4.

Most empirical studies have demonstrated that proximity is key to the usage of open spaces \cite{72,73}. Besides, Figure 4 reveals many other potential elements, among which facility, as an easily...
导致这一结果的原因可能是开放空间，尤其是公园中的设施类环境要素较其他场所中更为丰富，是最可能促进体力活动的环境要素类别。与社区量表相同，每份开放空间量表中都包含基础环境特征要素（数量占比范围为12%~22%）；整体主观评估因属非客观度量范畴，依然是此类量表涉及最少的要素类别。同时，开放空间量表中涉及对周边环境评估的指标相对较少（仅BRAT、CPAT、EAPRS和POST中涉及），事实上，因居民去往公园途中需穿越不同城市空间，这些空间的特征对居民的行为或感知产生的影响应予以考虑。

比较各开放空间量表发现，最全面的开放空间量表为BRAT与POST，其次为CPAT与EAPRS，这4份量表的指标数量相对较多，内容相对综合，可用于不同尺度的度量；涉及要素类别最少的量表是NEST与PARK（仅5类），两者侧重对开放空间内部环境进行简单快速度量，而较少考虑周边环境；NGST与PARA两份量表所涵盖的要素数量属中间水平，不包括主观评价、美观要素及周边环境，均从直接促进活动本身的角度度量园内各种具备活动支持潜力的要素。鉴于CPAT和POST应用较多，前者于2016年发展出应用程序eCAPT，后者分别于2010年和2018年发展出新西兰版本（NZ-POST）和应用App，这些版本都在不同程度上拓宽了量表应用范围并简化了工作流程。
Adolescents are a major user group of open spaces. Among the audit tools, CPAT and PARK are both youth-oriented but notably different: CPAT is suitable for all-age user measurement yet with an emphasis on teenagers, while PARK mainly measures the environmental factors especially facilities, encouraging adolescents’ physical activities. A large number of empirical studies also have proved that sound facilities facilitate teenagers’ exercise[79].

3.4.3 Audit Tools for Other Scenarios

In this paper, audit tools for other scenarios include the ones for workplaces, urban streets, and cities.

Workplace is a main scenario for physical activities besides communities and has received an increasing attention among researchers. Workplace audit tools are mainly used to measure outdoor walking spaces of a workplace (e.g., industrial and college campuses), represented by WWAT[48] and ISCOLE[80]. Containing 9 indicators, WWAT is suitable for all types of workplace with high user-friendliness and reliability. Nicholas D. Gilson adopted WWAT in an international cooperative study on major pedestrian routes of ten college campuses in seven countries and regions (Australia, Canada, England, Northern Ireland, Scotland, Spain, and the United States)[81], which discovered significant variations in support degree to physical activities among different campus environments: positive factors include pleasant sidewalks, less conflicts between walking and motor traffic, and conspicuous traffic signs, and passive factors include poorly connected road system. Such specific measurements and comparative studies can help clarify the distinctiveness of each campus and inform related improvement measures. ISCOLE, exclusively focusing on environmental factors of workplaces such as college campuses, measures recreational facilities and amenities (such as benches and drinking fountains), aesthetic factors, and the suitability for sports and general activities on playgrounds[40].

With an increasing popularity of pedestrian- and cyclist-friendly streets, routes, paths, and trails[82], planners and policymakers have started to value the significance in tourism, retail, downtown renewal, recreation, and culture propelled by outdoor activities[83]. Assisted by audit tools like PEAT, WABSA, and WRATS, recent studies on the associations between urban streets and physical activities have increased markedly. These tools are devised to measure streets’ physical settings, including basic road characteristics, facilities, and maintenance status, particularly the traffic conditions of intersections which would affect people’s willingness to travel.
Cities are huge, complicated systems. Audit tools for cities should be able to quickly measure a city’s overall characteristics. RALA and MIUDQRW, two representative tools, both develop overall index through the weighted combination model and regulate threshold(s) for Healthy City identification and grading, which facilitate comparative studies on the support degree to physical activities across cities or different areas within a city. RALA mainly measures factors of land use, subjective assessment, recreational facilities, basic characteristics, policy implementation, facility service condition (e.g., whether the facilities in public schools are available to the public in non-school hours), etc. MIUDARW is devised for measuring users’ experience and perception, focusing on the quantity and proportion of environmental factors (landmarks, public art, etc.) that would encourage or discourage physical activities.

3.4.4 Summary
To be brief, community audit tools emphasize the influences of social-ecological environment on citizens’ lifestyle, manifesting that active living could be supported by building safe communities with highly mixed land use. Open space audit tools examine various environmental factors that encourage people’s physical activities. Workplace and street audit tools primarily explore the environmental characteristics suitable for walking and cycling, and city audit tools allow for a general and quick review of a city’s support degree to physical activities.

4 Conclusion and Discussion
4.1 Existing Audit Tools and Development Trends
So far, audit tools for measuring built environment associated with physical activities in countries of the United States, Canada, Australia, etc. have developed systematic application procedures in academic research, planning practice, and policy-making.

This paper profiles the 26 audit tools for built environment measurement through a comparative analysis of indicator items to study their application suitability in urban planning research and practice. Diverse in forms, though, these audit tools have three aspects in common. First, these tools are all developed and applied in a same pattern (Fig. 5). Second, factors closely related to physical activities (accessibility, safety, etc.) appear with a higher frequency. Third, they are all easy to operate and sound in reliability, offering the same or similar measurement methods and indicator items for quick data collection and analysis.

Recently, two trends of audit tools have emerged:
1) Subdivided research on user groups. For example, the obesity rate of children and adolescents keeps increasing
5. Process of the preparation and application of audit tools

4.2 Enlightenments on Establishing the Urban Environmental Assessment System in China

Healthy environment planning and design in China is at its initial stage. Auditing of environmental factors’ influence on public health in urban environments is at its nascent stage, and there is a lack of systematic and targeted audit tools, especially at the micro level. This chapter reviews existing relevant research and studies and provides insights for the construction of a targeted urban environmental assessment system.

Study focus on the behavior patterns and living environment of this group of people, and thus编制环境量表以针对性地促进该类人群的体力活动。

2) Multi-source data and new technologies. To enhance the validity and reliability of audit tools and promote their application in environmental assessment and planning decision-making, studies are currently focusing on integrating multi-source data with field measurement. Preliminary measurements with online maps have proven to be more cost-effective and time-saving than on-site measurements, and can be used for situations where on-site measurements are difficult due to poor accessibility, etc. [85]~[87]. Additionally, development of audit tools based on mobile applications (Apps) supported by smart devices is a promising trend; these tools can collect, store, and analyze data, identify locations and spatial data, and record movement tracks.[50]~[78].

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量，因此有必要制定和推行符合中国国情的环境量表，构建较为全面的环境评估体系，从而指导健康城市设计。鉴于中国与欧美国家的社会背景、城市形态等存在差异，本研究建议中国学者在量表开发时特别考虑以下三点。

4.2.1 科学框架下的因地制宜

中国幅员辽阔，建成环境具有显著的地域差异和城乡梯度。因此，在度量城市潜在影响体力活动的环境要素时，跨城市及跨区域的横向比较非常必要。

本研究认为可通过两种途径推进量表构建，一是借鉴国际量表框架，并根据各地区实际情况对量表进行修订，以适应不同区域环境；二是通过现场调研以及进一步的文献梳理就某一类型的场地编制一份包含共性环境要素的量表，便于快速度量及进行城市/地域间的横向对比，以提供概略的基线对照。在进行指标筛选和设置计算方法时，应采用多利益相关方合作的方式对研究目标、研究对象、实地状况进行讨论，尽可能精准地选择指标，并对已构建的同类量表指标进行调控。例如，土地利用混合度在上述国外量表中权重较高，但中国的土地混合利用模式存在显著的城市形态差异，且封闭式小区等在一定程度上造成了碎片化空间和低使用率街道，可能使单纯的土地利用混合度指标对体力活动的预测性或解释程度非常有限。其次，在确定量表结构和指标前，需在不同时间、不同场景下进行度量，以充分校验量表——这是当前标准化度量中关键但又容易被忽视的环节。最后，可尝试将高效的机器学习算法引入标准化的度量过程，形成精细化、具体化且多层次的环境度量，实现动态监测与反馈。

4.2.2 对动态环境的适应

中国自20世纪90年代开始的快速城镇化加速了社会经济环境背景的演变，以及城市内部结构与外部轮廓的变化。同时，与体力活动密切相关的城市形态在宏观、中观和微观层面变化迅速。在量表设计中，针对转型过程中的建成环境与人群年龄结构变化，应在指标设定、计算方法等方面进行动态调整，以有效反映建成环境对体力活动的支持或阻碍程度。此外，快速转型过程中的社会文化及环境转变极大影响着公众参与度以及对城市环境的认知。因此，需要在量表设计中充分考虑不同人群的需求和行为模式，以便更准确地评估环境对体力活动的支持或阻碍程度。
These factors need to be attached importance in audit tool development and design interventions for positive activity spaces.

4.2.3 Interdisciplinary and Multi-Department Collaboration in Decision-Making

Interdisciplinary research is indispensable for built environment auditing and positive design intervention. Cross-department collaboration should be enhanced to propel relevant decision-making processes.

Macro-, meso-, and micro- audit tools can be used to inform master planning, regulatory planning, and detailed planning, respectively. In master planning, by overlapping environmental factors and public health data, it would be helpful to compare the impacts of these environmental factors across different cities and regions, providing a basis for optimal design. In the stages of regulatory planning, detailed planning, and urban design, audit tools provide guidelines for site design and for performance evaluation of planning and design. For planning management, audit tools could be used for performance monitoring and feedback collection to improve the coordination of decision-making. In addition, the promotion of audit tools benefits to increasing community governors’ health awareness, enhancing public participation, and improving public health level through bottom-up efforts.

4.3 Reflection

In China, empirical studies on physical activities and built environment are still inadequate in the diversity and systematism of research interests, which impedes the practice of health impact assessment and fails to offer intelligent support to positive intervention. This paper analyzes the existing audit tools for active living and summarizes the valuable knowledge and methods that can be used for developing audit tools. Given that it is difficult to comparatively study the efficiency and every indicator item among various audit tools, such differences are not examined in this paper. In the future, field measurements with same category audit tools should be conducted for more comprehensive and specific comparative studies.

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