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Auditing the representation of hormonal contraceptives in studies assessing exercise performance in women

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ABSTRACT

Hormonal contraceptive (HC) users have a different ovarian hormonal profile compared to eumenorrheic women. Due to the prevalence of HC use amongst sportswomen, there has been increased research efforts to understand their impact on exercise performance. The aim was to audit this research. Studies identified were assessed for HC type, athlete calibre, performance outcome, study design, and quality of methodological control regarding ovarian hormonal profiles. Sixty-eight different HCs were reported across 61 studies. Monophasic combined oral contraceptive (OCP) pills represented 60% of HCs, followed by other pills [34%, phasic-combined, progestogen-only, and un-specified], phasic and long acting reversible contraceptives [5%, vaginal ring, patch, implant, injection, intrauterine system] and unspecified HCs (1%). Eleven percent of participants using HCs were classified as highly trained or elite/international with no participants being classed as world class. Whilst the number of studies involving HCs has increased two-fold over the past decade, the number of studies ranked as gold standard has not increased (HC; 2003–57%, 2011–55%, 2022–43%. OCP; 2003–14%, 2011–17%, 2022–12%). Future research assessing HCs and exercise performance should adopt high-quality research designs and include a broader range of HCs in highly trained to world-class populations to increase the reach and impact of research in this area.

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Introduction

Hormonal contraceptives (HCs) disrupt the eumenorrheic ovarian hormonal profile by introducing exogenous synthetic hormones that act via negative feedback on gonadotrophic hormones. This chronic interference leads to the downregulation of the hypothalamic-pituitary-ovarian axis and the endogenous ovarian sex hormones, more specifically, oestrogen and progesterone. Contraceptive effects are achieved through the thickening of cervical mucus, thinning of the endometrial lining, and suppression of ovulation (Rivera et al., 1999). Consequently, the majority of HCs remove the endogenous cyclic ovarian hormonal fluctuations of the menstrual cycle, which is replaced with an exogenous hormonal profile and a suppressed endogenous profile. The exogenous profile varies depending on the specific type of HC used (Table 1). The intrauterine system [IUS], however, can have a more localised response to the exogenous progestogen, which means that some IUS users may present with regular menstruation and ovulatory cycles, as opposed to the suppressed endogenous profile seen with other HCs.

The use of HCs is prevalent among women across different athletic backgrounds, with varying types being favoured among these populations. For example, amateur, sub-elite, and elite female athletes playing a variety of sports from multiple countries have reported using HCs at rates ranging from 34% to 63% (Brown et al., 2023; Clarke et al., 2021; Ekenros et al., 2022; Langan-Evans et al., 2023; D. Martin et al., 2018; Oxfeldt et al., 2020). In a UK-based study, up to 64% of amateur, 58% of sub-elite, and 63% of elite athletes used combined oral contraceptive pills (OCPs) (Langan-Evans et al., 2023). Other forms, such as cyclic combined contraceptives (e.g., vaginal rings and patches) and long-acting reversible contraceptives (e.g., intrauterine systems, implants, injections), were also employed by approximately 40% of these athletes (Langan-Evans et al., 2023). Similar results were seen in a study conducted on elite athletes in Denmark, where ~72% used combined OCPs, and ~28% used other forms such as progestogen-only pills, cyclic contraceptives and long acting reversible contraceptives (Oxfeldt et al., 2020). Despite the range of contraceptive usage amongst active women, current research exhibits a notable bias towards studying the effects of combined OCP, particularly monophasic formulations (Elliott-Sale et al., 2020). These contraceptives may be favoured in the literature due to their prevalence among athletic populations and well-established characteristics and hormonal profiles. Nevertheless, data indicate that approximately 28–40% of amateur, sub-elite, and elite female athletes using HCs use long-acting HCs and progestogen-only contraceptives (Langan-Evans et al., 2023; D. Martin et al., 2018; Oxfeldt et al., 2020). Given the distinctive properties of long acting and progestogen-only contraceptives and their relatively high usage rates, it is essential to comprehensively understand their impact on exercise performance.

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The quality of the design and implementation of studies involving HCs (i.e., the standard of methodological control regarding ovarian hormonal profiles) is a topical theme to consider. A systematic review and meta-analysis conducted in 2020 assessing the influence of OCPs on exercise performance showed that 83% of studies demonstrated medium, low, or very low methodological quality (Elliott-Sale et al., 2020). Many of these articles failed to provide sufficient detail about the type of OCP used and the formulations of the contraceptive or length of usage, thus limiting study replication and the advancement of knowledge in the field. In 2022, an audit framework was developed to assess the representation of female athletes in sport science research (Smith et al., 2022). Within this audit, a tier system was created to rank studies using women based on the quality of methodological reporting for menstrual cycles, HCs, OCPs, and menstrual irregularities (Smith et al., 2022). This framework aligns with best practice recommendations from Elliott-Sale et al. (2021).

Therefore, the aim of this audit was to assess the representation of HCs in research examining exercise performance in women. The secondary aim was to assess the quality of methods used in research on HCs and exercise performance. With the complex ovarian hormonal profiles of HCs and high usage of HCs among athletic women, this project provides a greater understanding of their representation and methodological quality within the exercise performance literature.

Methods

Study search and selection

An electronic literature search was initially conducted in June 2023 using PubMed, SPORT discus and Web of Science followed by a repeat search in July 2023. Citation tracking on Google Scholar was used to identify any missed studies. Studies considered for inclusion were original peer reviewed articles (review and conference abstracts excluded), written in English and full text accessible with no date restriction. Population, intervention, study outcomes, and design are detailed in Table 2 and were used as the pre-defined inclusion criteria.

Search terms

Searches were conducted with the following terms: ("hormonal contraceptive" OR "oral contraceptives" OR "contraceptive injection" OR "contraceptive implant" OR "intrauterine system" OR "vaginal ring" OR "contraceptive patch" OR "hormone releasing intrauterine device" or "contraceptives") AND ("athletic performance" OR "sport performance" OR "muscular strength" OR "strength training" OR "muscular force" OR "power" OR "anaerobic" OR "anaerobic power" OR "anaerobic performance" OR "anaerobic capacity" OR "aerobic" OR "aerobic capacity" OR "aerobic power" OR "aerobic performance" OR "endurance" OR "endurance capacity" OR "endurance power" OR "endurance performance" OR "fatigue" OR "recovery").

Screening and selection

Rayyan software (https://www.rayyan.ai/) was used for the initial screening of the title and abstract. Searches from PubMed, SPORT discus and Web of Science were imported into the software and duplicates removed. Two researchers (TF, EC) independently screened each paper based on the predefined criteria (Table 2). Any conflicts were discussed and resolved between the two researchers; any continued conflicts were resolved by an independent researcher. Both researchers conducted full-text reviews.

Audit outcomes

The current study follows the recently published audit framework by Smith et al. (2022), with the following additions – type of HC and study design – and exceptions – study impact. These amendments were made to satisfy the current research question (i.e., with a greater focus on HCs than overall menstrual status).

Outcome 1. Type of hormonal contraceptive (HC)

The type of HC(s) used by study participants was extracted from each paper. The options were taken from Table 1 with the addition of options for un-specified HCs and un-specified OCPs (i.e., no further details were provided). To align with recent methodological recommendations for HC reporting (Elliott-Sale et al., 2021), brand and/or formulation and time since start of use was reported for each HC. In addition, a frequency count of the number of hormonal contraceptives included in the study is presented.

Outcome 2. Sample size and calibre of athlete

The number of women using each form of HCs was extracted from every paper alongside the total sample size. In addition, all details about participant training calibre were extracted from each paper. Using the information identified in the studies, each population was allocated an athlete calibre tier using an established framework (McKay et al., 2022). If no information was provided about athlete calibre, the sample was classified as *"did not state"*. For reference, the athlete calibre system has 5 tiers (see full text for inclusion criteria): Tier 0 (sedentary); Tier 1 (recreationally active); Tier 2 (trained/developmental); Tier 3 (highly trained/national); Tier 4 (elite/international); and Tier 5 (world-class) (McKay et al., 2022).

Outcome 3. Outcome of the study

The performance outcome of the study was extracted from each paper and classified into the categories stated in Table 2.

Outcome 4. Study design

How the use of HCs was incorporated within the research design of the study was extracted for each paper which specified HC type, which resulted in four categories (listed below with examples).

(1) HCs separated into single groups *(For example: separate groups of women using monophasic OCPs and progestogen only pills).*

Table 1. Hormonal contraceptives (HCs) considered for inclusion in the audit paper.

Type	Additional information	Example brands (UK)	Example exogenous hormones and concentrations for each brand	Usage
Oral Contraceptives				
Monophasic combined pill	Generation 2	Microgynon® Levest®	Ethinylestradiol: 30 µg Levonorgestrel: 150 µg	21 pills per packet (constant hormonal exposure)7-day pill free break
	Generation 3	Millinette 30® Femodene	Ethinylestradiol: 30 µg Gestodene: 75 µg	
	Generation 4	Yasmine® Lucette®	Ethinylestradiol: 30 µg Drospirenone: 3.0 µg	
Extended monophasic combined pill (28-day preparations)	Generation 2	Microgynon® 30 ED	Ethinylestradiol: 30 µg Levonorgestrel: 150 µg	28 pills per packet (21 active, 7 inactive)
	Generation 3	Femodene® ED	Ethinylestradiol: 30 µgGestodene 75 µg	
Phasic combined pill	-	Logynon®, TriRegol®	*Pill 1 (6 tablets)*- Ethinylestradiol: 30 µg Levonorgestrel: 50 µg *Pill 2 (5 tablets)*- Ethinylestradiol: 40 µg Levonorgestrel: 75 µg *Pill 3 (10 tablets)*- Ethinylestradiol: 30 µg Levonorgestrel: 125 µg	21 pills per packet (3 sections with different concentrations of hormones) 7-day pill free break
	-	Synphase®	*Pill 1 (7 tablets)* - Ethinylestradiol: 35 µg Norethisterone: 500 µg *Pill 2 (9 tablets)*- Ethinylestradiol: 35 µg Norethisterone: 1 mg *Pill 3 (5 tablets)*- Ethinylestradiol: 35 µg Norethisterone: 500 µg	
Extended phasic combined pill (28-day preparations)	-	Logynon® ED	*Pill 1 (6 tablets)*- Ethinylestradiol: 30 µg Levonorgestrel: 50 µg *Pill 2 (5 tablets)*- Ethinylestradiol: 40 µg Levonorgestrel: 75 µg *Pill 3 (10 tablets)*- Ethinylestradiol: 30 µg Levonorgestrel: 125 µg	28 pills per packet (3 or 4 sections with different concentrations of hormones) Can contain active and inactive pills
	-	Qlaira®	*Pill 1 (2 tablets)*- Estradiol valerate: 3 mg *Pill 2 (5 tablets)*- Estradiol valerate: 2 mg Dienogest: 2 mg *Pill 3 (17 tablets)*- Estradiol valerate 2 mg Dienogest 3 mg *Pill 4 (2 tablets)*- Estradiol valerate 1 mg *Pill 5 (2 tablets)*- No ingredient	
Progestogen only pill	-	Norgeston	Levonorgestrel: 30 µg	28 pills per packet, no break between pill packets
	-	Cerazette Cerelle	Desogestrel: 75 µg	
	-	Noriday	Norethisterone: 350 µg	
Cyclic Contraceptives				
Vaginal ring	-	NovaRing	Ethinylestradiol: 2.7 mg (0.015 mg per 24-h) Etonogestral: 11.7 mg (0.120 mg per 24-h)	Each ring lasts 21 days 7-day break
Patch	-	Evra	Ethinylestradiol: 600 µg (33.9 µg per 24-h) Norelgestromin: 6 mg (203 µg per 24-h)	Each patch lasts 7 days (use for 21 days) 7-day break
Long Acting Reversible Contraceptives				
Implant	-	Nexplanon	Etonogestrel: 60–70 µg/day for first 6 weeks. 35–45 µg/day at the end of year 1 30–40 µg/day at the end of year 2 25–30 µg/day at the end of year 3	3 years
Injection	-	Depo-Provera	Medroxyprogesterone acetate: 150 µg	13 weeks
	-	Sayana Press	Medroxyprogesterone acetate: 104 µg	13 weeks
	-	Noristerat	Medroxyprogesterone acetate: 200 µg	8 weeks
Intrauterine system	-	Mirena	Levonorgestrel (52 mg): 20 µg/day initially 18 µg/day after 1 year 12 µg/day after 4 years	3–6 years
	-	Levosert	Levonorgestrel (52 mg): 20 µg/day initially Declines progressively ~60% over 6 years	
		Kyleena	Levonorgestrel (19.5 mg)	
	-	Jaydess	Levonorgestrel (13.5 mg)	

(2) Grouped with other HCs *(For example: women taking monophasic OCPs grouped with women using vaginal rings or progestogen only pills).*
(3) Grouped with eumenorrheic women *(For example: women taking OCPs grouped with eumenorrheic women).*
(4) Grouped with men (*For example: All participants in the study grouped together).*

Outcome 5. Quality of methodological control

The quality of methodological control was assessed by two authors using an adapted version of the tier ranking system designed by Smith et al. (2022), both authors independently assessed all papers to ensure agreement. All studies were ranked using both the specific criteria for HC reporting ($n = 61$ studies ranked) and for OCP reporting ($n = 60$ studies ranked).

Table 2. Inclusion criteria based on population, intervention, study outcomes, and study design.

Population	Healthy cis-gendered women aged 18–40 years were considered for inclusion.No restrictions were put on activity level or training status.
Intervention	All participants were required to be taking a HC. All forms of HCs as listed in Table 1 were accepted. Participants could be taking the HC habitually or experimentally. Habitual and experimental were defined as per Elliott-Sale et al. (2020).
Study Outcomes	The primary outcome of each study was exercise performance. Studies were included if they met any of the following categories: • Athletic or sports performance (e.g., a mix of performance tests) • Strength or resistance training (strength training with strength testing e.g., 1 repetition maximum) • Muscular strength (isolated strength testing, e.g., maximum voluntary contraction) • Anaerobic power, or performance (e.g., maximum power) • Aerobic performance, or capacity (e.g., VO_{2max}) • Endurance performance, or capacity (e.g., time trial) • Fatigue/Recovery (e.g., muscle damage protocols)
Study Design	Any study design that included the above information was considered for inclusion.

Studies were ranked with both, to highlight the stricter criteria for OCP research to ensure homogeneity within participants using OCPs (Table 3). Based on the criteria in Table 3, studies were awarded either Gold, Silver, Bronze, or ungraded Tier. The annual cumulative paper count was calculated by summing the number of studies each year, while the methodological quality over time was assessed by calculating the percentages of gold, silver, bronze, and ungraded studies.

Results

The results from the identification and search strategy are presented in Figure 1. Table 4 summarises the studies included in the audit and the main outcomes.

Outcome 1. Type of hormonal contraceptive

In total, the 61 studies involved 68 separate investigations of HC use (Figure 2). The most commonly investigated HCs were monophasic combined OCPs, which were reported 41 times (60% of studies) followed by un-specified OCPs, which were reported 12 times. Other OCPs were reported sparingly (extended monophasic combined pills (28-days) = 3, phasic combined = 5 and extended phasic combined (28-day) = 2 and progestogen only pills = 1). Cyclic contraceptives were reported once (vaginal ring = 1) and long acting reversible contraceptives twice (Injection = 1, Intrauterine system = 1). One paper provided no details of type of HC, so was categorised as un-specified HCs. Brand of HC was provided for 21 out of 68 investigations of contraceptives. When the brand was not recorded, the composition or formulation of the HC was provided for 27 out of 47 contraceptives. Time since start of use was included in 54 out of 61 studies. Out of the 60 studies which specified HC type (including un-specified oral contraceptives), $n = 54$ reported one type of HC, $n = 5$ reported two types and $n = 1$ reported three types.

Outcome 2. Sample size and calibre of athlete

In total, 773 participants used HCs out of 1564 participants who participated in the 61 studies (49%). Out of 61 papers included in the audit, 13 assessed only women using HCs, whilst 48 assessed women using HCs, alongside either women not using HCs or men. The lowest sample size of HC users was $n = 5$ from a total of 15 participants, which the highest involved $n = 43$ from a total of 82 participants. Out of 773 participants, 83 participants (11%) were unable to be classified into an athlete calibre tier. Out of the remaining 690 participants: 178 (26%) were classified as Tier 0 (sedentary); 272 (39%) were classified as Tier 1 (recreationally active); 159 (23%) were classified as Tier 2 (trained/developmental); 59 (9%) were classified as Tier 3 (highly trained/national); 22 (3%) were classified as Tier 4 (elite/international); and 0 were classified as Tier 5 (world-class).

Outcome 3. Outcome of the study

In total, 8 different outcomes were investigated across the 61 studies. From highest to lowest, 17 studies had

Table 3. Criteria for each tier system for quality of methodological control adapted from Smith et al., 2022 based on Elliott-Sale et al., 2021.

Tier	Oral contraceptive pill (OCP) criteria	Hormonal contraceptives (HC) criteria
Gold	Three of three stated: OCP use ≥3 months prior to recruitment (i.e., length of usage),with the type (e.g., mono, bi, or triphasic; combined or progesterone only and formulation [name and concentration of exogenous hormones]) stated. Stipulate and consider OCP taking (i.e., active OCP) days and OCP free (i.e., inactive/placebo OCP) days. *One brand/type/generation of OCP per group of participants*	Three of three stated: HC use ≥3 months prior to recruitment (i.e., length of usage), with the type (e.g., implants, injections, intrauterine devices/ coils that are hormone releasing and NOT copper-based, vaginal rings, contraceptive transdermal patches), and formulation (e.g., combined or progesterone only, names and concentration of exogenous hormones) stated. *One type of HC per group of participants*
Silver	Two of three stated: OCP length of usage, type, and formulation, Do/do not stipulate and consider OCP-taking (i.e., active OCP) days and OCP-free (i.e., inactive/placebo OCP) days. *One or more than one brand/type/generation of OCP per group of participants*	Two of three stated: HC length of usage, type, and formulation *One or more than one type of HC per group of participants*
Bronze	One of three stated: OCP length of usage, type, and formulation. Do not stipulate and consider OCP taking (i.e., active OCP) days and OCP free (i.e., inactive/placebo OCP) days. *More than one brand/type/generation of OCP per group of participants*	One of three stated: HC length of usage, type, formulation *More than one type of HC per group of participants*
Ungraded	Insufficient detail to award a gold, silver, or bronze	Insufficient detail to award a gold, silver, or bronze

OCP criteria has been updated from Smith et al. (2022) to include generation (alongside brand/type) to aid understanding in the context of this audit.

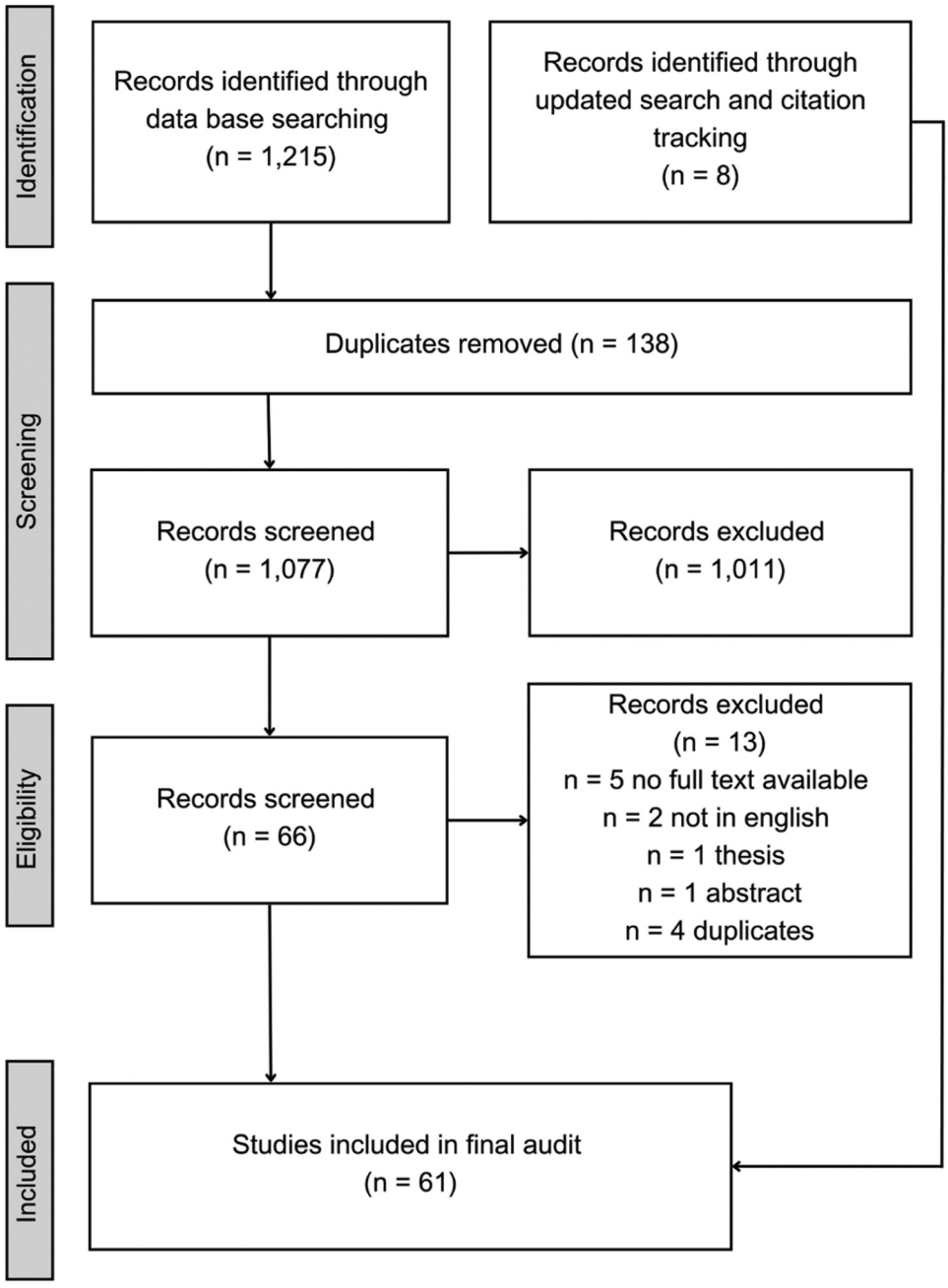

Figure 1. Flow diagram of studies.

endurance performance/capacity outcomes, 17 had muscular strength outcomes, 10 had sports performance outcomes, 5 had anaerobic power/performance outcomes, 4 had strength training outcomes, 4 had aerobic power/performance outcomes, 4 had fatigue/recovery outcomes.

Outcome 4. Study design

Figure 3 shows the breakdown of the studies by study design; 85% of studies included in the audit (including studies with un-specified HC and OCPs) split different types of HCs into individual groups, with 11% of studies grouping different contraceptives together, 3% grouping HCs with eumenorrheic women, and 0% grouping HCs with men. In addition, although no studies grouped HCs with men, some studies did include men who were grouped separately.

Outcome 5. Quality of methodological control

Quality of methodological control was assessed using the criteria outlined by Smith et al. (2022) for HCs (Figure 4a) and specifically for OCPs (Figure 4b). When assessed against the HC criteria, 43% of studies were awarded gold tier, 38% silver tier, 16% bronze tier, and 3% ungraded. When assessed against the OCP criteria, 12% of studies were awarded gold tier, 55% silver tier, 27% bronze tier, and 7% ungraded. Figure 5 shows the yearly distribution of

Table 4. All studies included in the audit and the outcomes.

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5		
Reference	HCs included *(Brand/Formulation included)*	Athlete calibre	Outcome of study	Study design	Quality tier (HC)	Quality tier (OCP)	Missing quality criteria
Ali et al. (2016)	Monophasic combined pill *(brand and formulation)*	Tier 2: Trained/ Developmental	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Anderson et al. (2017)	Monophasic combined pill *(no brand/formulation)*	Tier 0: Sedentary	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Formulation/Brand
Armstrong et al. (2005)	Un-specified oral contraceptives *(brand)* Injection *(brand)*	Tier 0: Sedentary	Athletic/Sports Performance	2. Grouped with other contraceptives	Silver	Silver	Type of HC One type of HC per group One brand/generation per group
Bell et al. (2011)	Monophasic combined pill *(no brand/formulation)*	Tier 1: Recreationally Active	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Silver	Formulation/Brand One brand/generation per group
Bozzini et al. (2021)	Un-specified oral contraceptives *(no brand/formulation)*	Tier 3: Highly trained/national	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC One type per group Formulation/Brand Active/Inactive days
Bryner et al. (1996)	Monophasic combined pill *(formulation)*	Does not state	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	Active/Inactive days
Casazza et al. (2002)	Extended phasic combined pill *(formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Dalgaard et al. (2019)	Monophasic combined pill *(brand and formulation)*	Tier 0: Sedentary	Strength or Resistance Training	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group Active/inactive days
Dam et al. (2022)	Monophasic combined pill *(brand and formulation)*	Tier 1: Recreationally Active	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Drake et al. (2003)	Un-specified oral contraceptives *(no brand or formulation)*	Does not state	Muscular Strength	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC One brand/generation per group Formulation/Brand Active/inactive
Ekenros et al. (2013)	Monophasic combined pill *(formulation)*	Tier 1: Recreationally active	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Length of usage
Elliott et al. (2005)	Monophasic combined pill *(brand and formulation)*	Tier 0: Sedentary	Muscular Strength	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Giacomoni and Falgairette (1999)	Monophasic combined pill *(formulation)*	Does not state	Anaerobic Power/ performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group Active/inactive days
Giacomoni et al. (2000)	Monophasic combined pill *(formulation)*	Does not state	Anaerobic Power/ performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group Active/Inactive days
Gordon et al. (2013)	Monophasic combined pill *(no brand/formulation)*	Tier 2: Trained/ Developmental	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	One brand/generation per group Formulation/Brand Active/Inactive days
Gordon et al. (2017)	Monophasic combined pill *(formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	Active/Inactive days
Grucza Pekkarinen et al. (1993)	Monophasic combined pill *(brand and formulation)* Phasic combined pill *(brand)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	2. Grouped with other contraceptives	Silver	Silver	One type of HC per group One brand/generation per group Active/Inactive days
Hicks et al. (2017)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Fatigue/Recovery	1. Hormonal contraceptives separated into single groups	Silver	Silver	Formulation/Brand One brand/generation per group
Isacco et al. (2015)	Monophasic combined pill *(formulation)*	Tier 1: Recreationally active	Aerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group

(*Continued*)

Table 4. (Continued).

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5		
Reference	HCs included *(Brand/Formulation included)*	Athlete calibre	Outcome of study	Study design	Quality tier (HC)	Quality tier (OCP)	Missing quality criteria
Joyce et al. (2013)	Monophasic combined pill *(formulation)*	Tier 2: Trained/ Developmental	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Joyce et al. (2014)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Fatigue/Recovery	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Brand/Formulation
Lebrun et al. (2003)	Phasic combined pill *(brand and formulation)*	Tier 2: Trained/ Developmental	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Lee et al. (2014)	Monophasic combined pill *(formulation)*	Tier 0: Sedentary	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	One brand/generation per group Formulation/Brand Active/inactive days
Lei et al. (2019)	Monophasic combined pill *(brand and formulation)*	Tier 2: Trained/ Developmental	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group Active/inactive days
Loureiro et al. (2011)	Un-specified oral contraceptives *(no brand or formulation)*	Tier 1: Recreationally active	Muscular Strength	3. Grouped with eumenorrheic women	Bronze	Bronze	One type of HC per group Type of HC Brand/formulation Active/Inactive
Lynch et al. (2001)	Monophasic combined pill *(brand and formulation)*	Tier 0: Sedentary	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Lynch and Nimmo (1998)	Monophasic combined pill *(brand and formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Mackay et al. (2019)	Monophasic combined pill *(formulation)*	Tier 0: Sedentary	Fatigue/Recovery	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group Active/inactive days
A. C. Martin et al. (2019)	Un-specified oral contraceptives *(no brand or formulation)*	Tier 3: Highly trained/national	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Ungraded	Ungraded	Type of HC Formulation/Brand Length of usage Active/inactive days
Mattu et al. (2020)	Monophasic combined pill *(formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Minahan et al. (2015)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Formulation/brand
Myllyaho et al. (2021)	Monophasic combined pill *(formulation)* Progestogen only pill *(formulation)* Intrauterine system *(formulation)*	Tier 1: Recreationally active	Athletic/Sports Performance	2. Grouped with other contraceptives	Silver	Silver	One type of HC per group One brand/generation per group Active/Inactive days
Nichols et al. (2008)	Un-specified oral contraceptives *(no brand or formulation)*	Tier 4: Elite/ international	Strength or Resistance Training	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC One brand/generation per group Active/Inactive days
Nicolay et al. (2007)	Monophasic combined pill *(no brand or formulation)*	Does not state	Muscular Strength	1. Hormonal contraceptives separated into single groups	Bronze	Ungraded	One brand/generation per group Formulation/Brand Length of usage Active/inactive days
Notelovitz et al. (1987)	Un-specified oral contraceptives *(brand and formulation)*	Tier 2: Trained/ Developmental	Aerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Silver	Bronze	Type of HC One brand/generation per group Active/inactive days

(*Continued*)

Table 4. (Continued).

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5		
Reference	HCs included *(Brand/Formulation included)*	Athlete calibre	Outcome of study	Study design	Quality tier (HC)	Quality tier (OCP)	Missing quality criteria
Peters and Burrows (2006)	Monophasic combined pill *(formulation)*	Tier 2: Trained/ Developmental	Muscular Strength	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Quinn et al. (2018)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Aerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Formulation/brand
Rebelo et al. (2010)	Un-specified oral contraceptives *(formulation)*	Tier 0: Sedentary Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Silver	Bronze	Type of HC Active/inactive days
Rechichi et al. (2008)	Extended monophasic combined pill *(formulation)*	Tier 2: Trained/ Developmental	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Rechichi and Dawson (2009)	Extended monophasic combined pill *(formulation)*	Tier 3: Highly trained/national	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Rechichi and Dawson (2012)	Extended monophasic combined pill *(formulation)*	Tier 3: Highly trained/national	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Redman and Weatherby (2004)	Extended phasic combined pill *(brand and formulation)*	Tier 3: Highly trained/national	Anaerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Rickenlund et al. (2004)	Monophasic combined pill *(formulation)*	Tier 2: Trained/ Developmental	Athletic/Sports Performance	1. Hormonal contraceptives separated into single groups	Gold	Gold	
Riechman and Lee (2022)	Monophasic combined pill *(brand and formulation)* Phasic combined pill *(brand and formulation)*	Tier 1: Recreationally active	Strength or Resistance Training	2. Grouped with other contraceptives	Silver	Bronze	One type of HC per group One brand/generation per group Length of usage Active/inactive days
Romance et al. (2019)	Monophasic combined pill *(formulation)* Phasic combined pill *(formulation)*	Tier 2: Trained/ Developmental	Strength or Resistance Training	2. Grouped with other contraceptives	Silver	Silver	One type of HC per group One brand/generation per group Active/Inactive days
Sarwar et al. (1996)	Monophasic combined pill *(no brand or formulation)*	Tier 0: Sedentary	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	One brand/generation per group Formulation/brand Active/inactive days
Savage and Clarkson (2002)	Un-specified oral contraceptives *(no brand or formulation)*	Does not state	Fatigue/Recovery	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC One type of HC per group One brand/generation per group Formulation/brand
Schaumberg et al. (2017)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Aerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Silver	Silver	One brand/generation per group Formulation/brand
Simpson et al. (2018)	Monophasic combined pill *(no brand or formulation)*	Tier 0: Sedentary	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	Formulation/brand Active/inactive days
Sims et al. (2007)	Phasic combined pill *(no brand or formulation)*	Tier 2: Trained/ Developmental	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Bronze	Ungraded	One brand/generation per group Formulation/brand Length of usage
Sousa et al. (2020)	Un-specified oral contraceptives *(no brand or formulation)*	Tier 2: Trained/ Developmental	Muscular Strength	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC One brand/generation per group Formulation/brand Active/inactive days
Sunderland et al. (2011)	Monophasic combined pill *(brand)*	Tier 2: Trained/ Developmental	Anaerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Sunderland and Nevill (2003)	Monophasic combined pill *(brand)*	Tier 2: Trained/ Developmental	Anaerobic Power/ Performance	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group

(*Continued*)

Table 4. (Continued).

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5		
Reference	HCs included *(Brand/Formulation included)*	Athlete calibre	Outcome of study	Study design	Quality tier (HC)	Quality tier (OCP)	Missing quality criteria
Sung et al. (2022)	Monophasic combined pill *(no brand or formulation)*	Tier 0: Sedentary Tier 1: Recreationally active	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	One brand/generation per group Formulation/brand Active/inactive days
Taipale-Mikkonen et al. (2021)	Monophasic combined pill *(brand)* Vaginal Ring *(brand)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	2. Grouped with other contraceptives	Silver	Silver	One type of HC One brand/generation per group
Thompson et al. (2021)	Monophasic combined pill *(brand and formulation)*	Does not state	Muscular Strength	1. Hormonal contraceptives separated into single groups	Gold	Silver	One brand/generation per group
Vaiksaar et al. (2011)	Monophasic combined pill *(formulation)*	Tier 4: Elite/ international Tier 1: Recreationally active	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Gold	Silver	Active/inactive days
Weidauer et al. (2020)	Monophasic combined pill *(no brand or formulation)*	Tier 1: Recreationally active	Muscular Strength	1. Hormonal contraceptives separated into single groups	Silver	Bronze	One brand/generation per group Formulation/brand
Wickham et al. (2019)	Un-specified hormonal contraceptives *(no brand or formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	2. Grouped with other contraceptives	Bronze		Type of HC Formulation/brand
Wirth and Lohman (1982)	Un-specified oral contraceptives *(no brand or formulation)*	Does not state	Endurance Performance/ Capacity	1. Hormonal contraceptives separated into single groups	Bronze	Bronze	Type of HC Formulation/brand Active/inactive
Yanovich et al. (2019)	Un-specified oral contraceptives *(no brand or formulation)*	Tier 1: Recreationally active	Endurance Performance/ Capacity	3. Grouped with eumenorrheic women	Ungraded	Ungraded	Type of HC Formulation/brand Length of usage

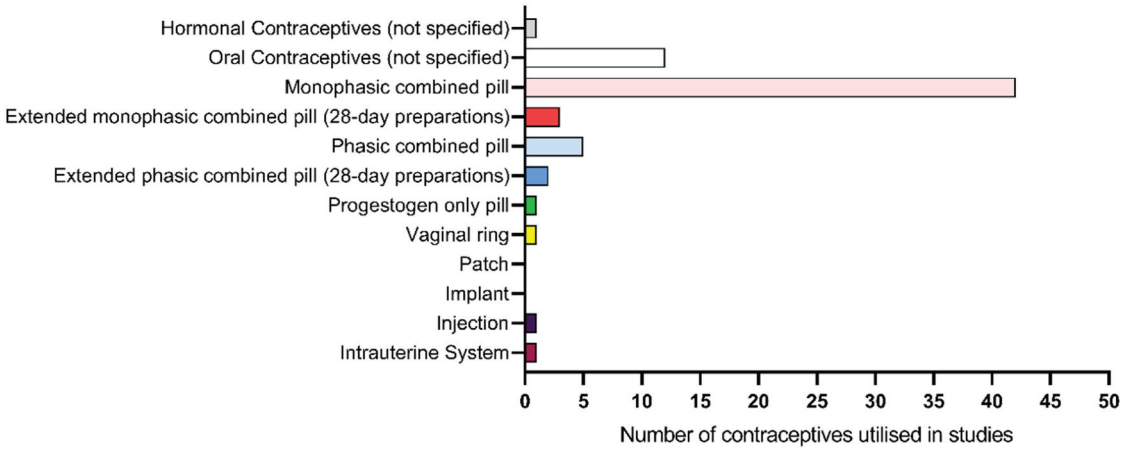

Figure 2. Types of HCs investigated in the studies within the audit. Note. Some of the 61 studies investigated had more than one type of HC, providing a total of 68 separate investigation of HCs.

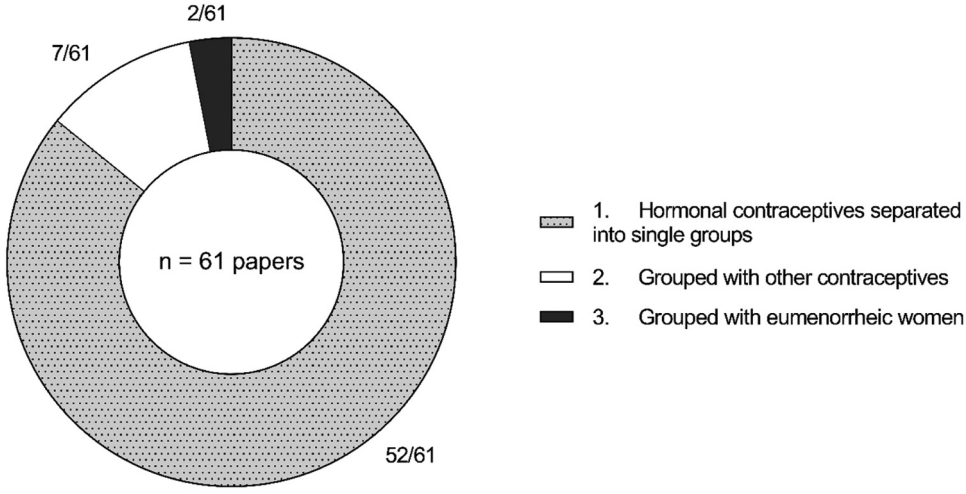

Figure 3. Study design: how the HCs were incorporated within the research design of the study. Note. Figure 3 includes studies where un-specified OCPs were reported which could inflate the outcomes presented due to difficulties in knowing which OCPs were used (see Table 1 for types of OCP which could be included in these studies).

tier rankings for HCs (Figure 5a) and specifically for OCPs (Figure 5b) alongside the yearly distribution frequency of publications since 1982. Percentage of gold rankings has not improved since 2003. When assessed against the HC criteria, gold rankings accounted for in 57% in 2003, 55% in 2011, 43% in 2022. When assessed against the OCP criteria gold rankings accounted for in 14% in 2003, 17% in 2011, 12% in 2022.

Discussion

The study aimed to assess the representation of HC use by female participants involved in research examining exercise performance, with a secondary objective of evaluating the quality of methods used in research on HCs and exercise performance. The main finding of this audit is the predominant focus on monophasic combined OCPs in research, while cyclic and long-acting reversible contraceptives are notably underrepresented, being investigated in less than 5% of all studies of HCs. In addition, female athletes are underrepresented in the literature examining HCs and exercise, the majority (70%) of research participants in the available literature were either unclassified, sedentary (Tier 0) or recreationally active (Tier 1). Indeed, elite athletes (Tier 4) account for only 3% of the populations studied and no studies have included world-class athletes (Tier 5).

Monophasic OCPs represented 60% of the HCs investigated in the studies included in the audit, with ~34% being other forms of OCPs [phasic, extended, progestogen-only, or unspecified]. Conversely, less than 5% of the HCs used in the studies included in the audit were long-acting reversible or cyclic contraceptives. This is noteworthy, given that recent studies, such as Langan-Evans et al. (2023), have indicated a substantial uptake of the use of non-OCPs in athletic populations sampled in the UK (42%), including intrauterine devices/systems (IUD/IUS): 21%; implants (17%); injections (3%); and vaginal rings (1%). Similar numbers were shown in studies in other countries: Denmark; ~20% (Oxfeldt et al., 2020), Australia ~20% (Clarke et al., 2021), Sweden ~44% (Ekenros et al., 2022). Given the unique properties of each type of HC (i.e., variability in delivery

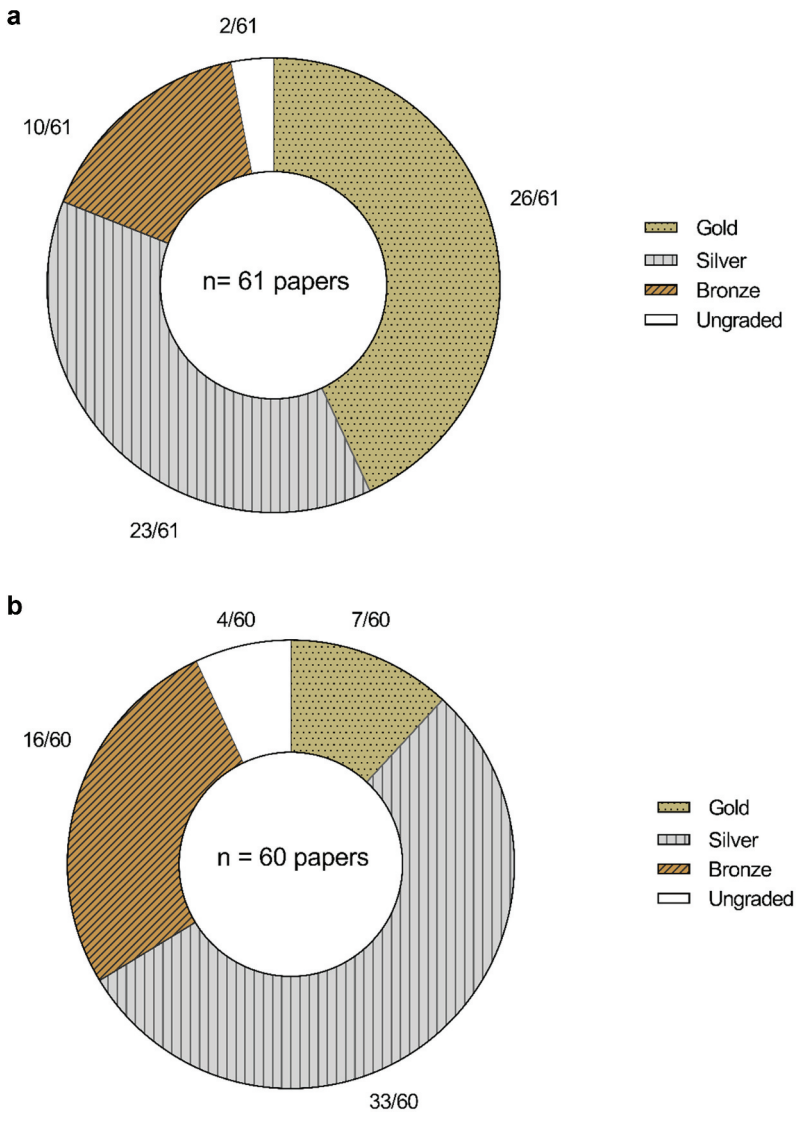

Figure 4. Standard of methodological control when assessed by (a) HC tier system and (b) OCP tier system.

methods and exogenous hormone profiles), there is an imperative need to expand future research to include a broader range of HC types, including cyclic and long-acting reversible options that are currently prevalent. This comprehensive approach is vital for understanding the distinct influences of each contraceptive method on exercise performance.

It should be noted that the studies included in this audit span 37 years and therefore include a range of older and newer HC formulations. Any obsolete HCs included in this audit are not intended to represent or to be considered in the same way as current HCs, rather their inclusion charts the historical timeline of research in this area and highlights the need for future research to not just consider the trend in the types of HCs used by active women but also the advances and evolution of HC formulations.

Most studies included in this audit focussed on sedentary and recreationally active participants (Tier 0 and Tier 1 ~ 58% overall participants); compared with 21% trained/development (Tier 2), 8% highly trained/national (Tier 3) and 3% elite athletes (Tier 4). However, 11% of participants were unable to be classified due to the lack of information on athlete training status, potentially over or underestimating the reported categories. Therefore, it is crucial that future research provides sufficient information regarding participant characteristics and training level (see McKay et al. (2022) for full details). Several studies (Clarke et al., 2021; Langan-Evans et al., 2023; Oxfeldt et al., 2020; Parker et al., 2022), have reported varying usage rates of HCs in elite athletes, with Langan-Evans et al. (2023) indicating a prevalence of 37% among the elite population. This disparity raises concerns, given the physiological and training discrepancies between elite athletes and recreational participants and the lack of research in elite populations (3%). Consequently, findings from research involving sedentary or recreational populations may not be directly applicable to elite athletes (Burden et al., 2021). Therefore, there is a compelling need for future research, specifically tailored to elite athletes using HCs, to comprehensively understand the physiological effects of HC on high-level exercise performance. Such research is essential for providing evidence-based guidelines that are directly relevant to all athletic populations.

Over the past decade (2011–2022), there has been a notable surge in the annual publication of research studies in this area, averaging approximately 3 studies per year, compared to the preceding 15 years (1996–2010), which showed an average of approximately 1.5 studies per year (Figure 5). Here, we note that the first study for inclusion in the audit was published in 1987; more than two decades after the introduction of HCs to market in most countries. Despite this surge in research output, the number of studies achieving a gold ranking has not improved since 2003. When assessed against the HC criteria, gold rankings accounted for 57% of studies published in 2003, 55% in 2011, and 43% in 2022. When assessed against the OCP criteria, gold rankings accounted for 14% in 2003, 17% in 2011, and 12% in 2022. Notably, within the reviewed literature, one paper omitted the specification of the HC type employed in the study, and twelve studies omitted the specification of OCP type emphasising the need for comprehensive reporting of HC details. Another study included a participant using a vaginal ring with a group of participants using monophasic OCPs; however, despite both being combined contraceptives, they have distinct differences in concentrations of exogenous hormones and delivery/timing of these hormones. These findings highlight the opportunity for improvement in methodological quality and reinforce the imperative for future research to encompass all relevant information regarding HC usage.

All studies were evaluated using the HC and OCP guidelines (Smith et al., 2022). When evaluated using only the HC guidelines, 43% of studies achieved a gold-tier rating. In contrast, only 12% of studies attain a gold-tier rating when assessed against OCP guidelines. This discrepancy highlights the stricter criteria of the OCP guidelines, twenty studies were demoted from gold to silver ranking when assessed against the OCP guidelines. Within these twenty, three studies failed to account for active/inactive days (Bryner et al., 1996; Gordon et al., 2017; Vaiksaar et al., 2011), thirteen studies included more than one contraceptive generation (Elliott et al., 2005; Isacco et al., 2015; Joyce et al., 2013; Lynch & Nimmo, 1998; Lynch et al., 2001; Mackay et al., 2019; Mattu et al., 2020; Rechichi & Dawson, 2012; Rechichi et al., 2008; Sunderland & Nevill, 2003; Sunderland et al., 2011; Thompson et al., 2021) and four studies did both (Dalgaard et al., 2019; Giacomoni & Falgairette, 1999; Giacomoni et al., 2000; Lei et al., 2019). This implies that the number of studies ranked as gold could potentially have increased from 7 to 27, which would equate to nearly 45% of studies achieving a gold ranking if authors had included details about active and inactive pill phases and had separated different generations of pills. Separation of pill generations is recommended due to variations in endogenous hormone concentrations, progestin potency, androgenic and antiestrogenic properties (Elliott-Sale et al., 2013, 2021). Furthermore, it

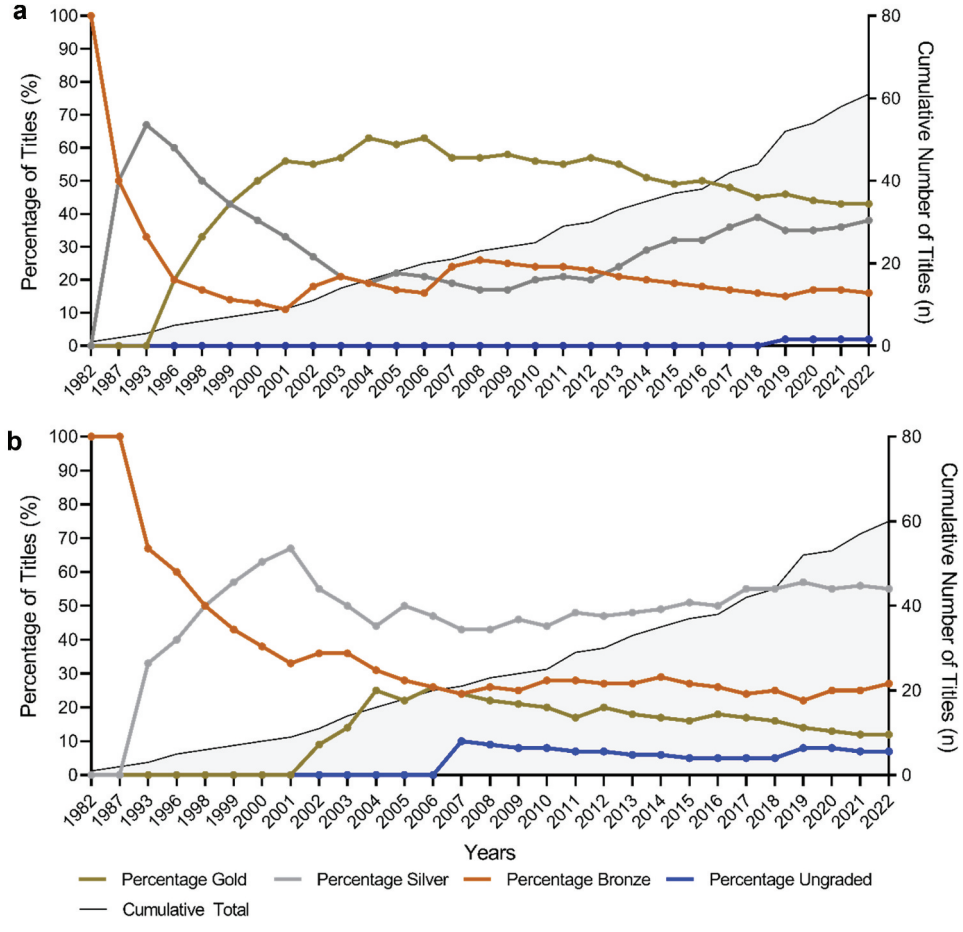

Figure 5. Yearly distribution of tier rankings for (a) HCs and (b) OCPs specifically alongside the cumulative total of papers.

is crucial to emphasise that achieving a gold ranking in reporting criteria does not require time-consuming or resource-intensive procedures. Researchers can meet these criteria by providing essential information on HCs, including details such as type, formula, brand, duration of usage, and specification of active and inactive pill phases. Additionally, research quality significantly benefits from avoiding the combination of different generations of OCPs within the same group. We acknowledge that, with the many formulations of OCPs available to women, restricting participants to one generation of combined monophasic OCP may limit the potential sample size, increase the time taken to recruit and complete the study, and possibly inflate study costs, however, by restricting to one generation methodological quality (i.e., homogeneity) will be improved. There is a compelling need to enhance the quality and reporting standards of HC research. The limitations identified during this audit can provide valuable insight to inform decisions for shaping the direction of future research methods and ensuring the production of high-quality information on HCs and exercise performance which can be effectively utilised.

Another limitation in the current body of research on HCs and exercise performance is the predominant focus on certain outcome measures; specifically, out of the 61 total studies included in the audit, a high percentage were focused on endurance performance (28%) and muscular strength (28%) outcomes. The high concentration of research into these areas may not provide a comprehensive understanding of the potential effects of HCs on various aspects of exercise performance such as fatigue, recovery, and training. In addition, only three studies included HCs other than OCPs ($n = 1$ intrauterine system, $n = 1$ injection and $n = 1$ vaginal ring), in two of these studies these HCs were grouped with a form of OCP, which may limit our insights into the unique impacts phasic and long acting reversible contraceptives. To further advance knowledge in the field, researchers should diversify their approach to include various types of HCs across a broader range of outcome measures, this comprehensive approach will contribute to our understanding of how HCs may influence various types of exercise performance.

In conclusion, this audit highlights the need for greater diversity in the types of HCs investigated or included in exercise research, particularly the inclusion of cyclic and long-acting reversible options. It also underscores the importance of conducting research on all populations, including elite populations, to ensure findings are applicable to these specific population requirements. Furthermore, the audit emphasises the value of improving reporting standards and methodological rigour in HC research, with recognition that achieving these standards often requires small and simple adjustments. These improvements are essential to enhance the quality and comparability of future findings.

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